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Title Nymphon (Pycnogonida) in the Eastern Arctic

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Nymphon (Pycnogonida) in the Eastern Arctic.

A thesis submitted to the Council for National Academic Awards in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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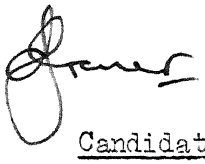
July 1982.

CERTIFICATE.

While registered as a candidate for the degree of Doctor of Philosophy for the C.N.A.A., the author has not been a registered candidate for another award of the C.N.A.A., or of a university or other establishment. No material contained in this thesis has been used in any other submission for an academic award.

Signed. 

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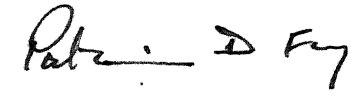
Signed. 

Director of Studies.

ACKNOWLEDGEMENTS.

This thesis is dedicated to Bill Fry for all his help, energy and friendship. I sincerely hope that this thesis is worthy of one of his students.

In such a ramified work as this it is easy to omit people to whom I owe gratitude. If this has been the case it is due to my addled brain and not discourteousness.

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NYMPHON (PYCNOGONIDA) IN THE EASTERN ARCTIC PhD THESIS

GARY JOHN CRANMER JULY 1982

ABSTRACT.

Nymphon is the largest genus of Pycnogonida reaching its greatest diversity in the Polar regions. A revision of the genus within the Eastern Arctic has proved necessary due to the numerous nomenclatural complexities which have accumulated in the literature since its last major revision by Sars in 1891.

This has been achieved using multivariate analyses involving the measurement of over 1500 specimens. Fifteen species are now recognized from the area and each has been redrawn and redescribed. It has not proved necessary to propose any new species.

Two distinct sub-groups are found within the genus in this area, differing in leg morphology and reproductive strategy. The first group, exemplified by Nymphon strömi, has a leg morphology suited to walking or striding. A large number of lightly yolked eggs are typically produced and the larvae spend only a short period of their development on the male ovigers before they disperse. The other group, exemplified by Nymphon hirtipes, has a leg morphology more suited to clinging. Fewer eggs are produced but these are richer in yolk and the male overwinters with the larvae which are lost only when metamorphosis is nearly complete.

These interspecific differences have been discussed and it is thought that they may enable direct competition to be avoided by the exploitation of different facets of the same environment. In addition, differences in the musculature have been discussed for species within Nymphon and for the Pycnogonida generally.

The male ovigers of all species examined show various adaptations which increase the surface area compared with that of the female. These modifications have been discussed and are shown to afford a greater area for attachment of the maturing egg masses.

A histological examination of the internal structure of the femoral cement glands of Nymphon hirtipes has revealed that the adult males have a broad band of glandular tissue lying under the epidermis whereas specimens in the final larval stage have little or none.

The life-cycle of Nymphon hirtipes is postulated, showing the species to take between two and a half and three years to attain maturity. It breeds only once, during its final summer. This is compared with existing knowledge of the life cycles of shallow and tropical water species.

CONTENTS.

1. GENERAL INTRODUCTION.

The Pycnogonida Latreille 1810, or seaspiders, are a little known group of marine arthropods which have, over the past 100 years, attracted the attentions of such distinguished biologists as E.L.Bouvier; L.J.Cole; A.Dohrn; J.W.Hedgpeth; P.P.C.Hoek; A.M.Norman; G.O.Sars; W.Schimkewitsch; K.Stephensen and E.B.Wilson.

They are represented in all parts of the world ocean, being widely distributed from the tropics to the poles and from the littoral zone to depths greater than 6000 metres.

Although Fry (1964) points out that as far as is known pycnogonids are not more abundant in any one part of the world than another, certain genera do appear to be more abundant in some areas than in others. The genus Nymphon Fabricius 1794 attains its greatest diversity within polar regions and some of its species are locally very abundant. N.hirtipes Bell 1853 appears to achieve the greatest abundance of all, having been recorded at a maximum density of approximately $40/m^2$ near Isfjord, Spitsbergen. This estimate is made with reasonable confidence, and N.hirtipes is therefore a species well worthy of consideration in any study of the larger epibenthic components of the fauna.

In feeding, pycnogonids appear to be 'discerning catholics' showing a preference for hydroids and anthozoans, but also feeding on many other soft bodied animals such as holothurians, molluscs and tunicates.

The extent to which pycnogonids suffer predation is completely unknown. Of the many thousands of fish stomachs which have been sampled, less than one in a thousand has been found to contain pycnogonids (Stephensen, 1937; Rae, 1956) although two specimens of Pycnogonum littorale Strøm 1762 have been observed in the stomach of

cod (personal observation), but both were alive and the possibility exists that they were only taken when the fish was in the trawl. Dearborn (1967) has reported that pycnogonids form a small percentage of the diet of the large antarctic isopod Glyptonotus antarcticus and Hedgpeth (1952) reports that the large green anemone of the Californian coast, Anthropleura xanthogrammica, will eat Pycnogonum stearnsi Ives 1892. However, these remain the only reports of 'predation' and it is therefore possible that pycnogonids are in general not preyed upon, but rather form a slow shunt in a similar way to many echinoderms, releasing their energy back into the food-web only after death.

There is a great variation in the size of pycnogonids. The smallest are found in shallow tropical waters, having a leg-span of less than three millimetres. The largest in leg-span is the ubiquitous deep water species Colossendeis colossea Wilson, 1881 which can achieve a size of over fifty centimetres. However, in total body mass the largest species is Dodecopoda mawsoni Calman and Gordon, 1933 from antarctic waters.

The Pycnogonida are perhaps the nearest any animal comes to being all legs and no body. General pycnogonid morphology consists of a reduced body comprising a slender trunk of four to six segments or somites, an anterior tripartite proboscis (which in some species may be over four times the body length, but is usually about half the length of the body) and a posterior, unsegmented abdomen. All appendages arise from the trunk somites. The first, or cephalic, somite is the largest, bearing the chelicerae, palps, ovigers, first pair of walking legs and, mediodorsally, an ocular tubercle bearing four pigmented eyes, though in deep water and cryptic species eyes are lacking or the ocular tubercle is absent. The remaining somites each bear a pair of walking legs, and the hindmost bears also the abdomen. In the vast majority of species the trunk comprises four somites, with four pairs of walking legs. However, three families,

the Pycnogonidae, Nymphonidae and Colossendidae, include species possessing five somites, and the latter two have species with six somites, with ten and twelve legs respectively.

The three pairs of anterior appendages - chelicerae, palps and ovigers - are not present in all genera. The chelicerae, which aid in feeding, comprise a cylindrical scape of one or two segments and a chela bearing a movable and immovable finger, which may or may not bear dentition. The palps may be formed from as many as twenty segments, as in Nymphonella tapetis Ohshima, 1927, but between five and ten segments is usual. The function of the palps is not fully known but in the larger colossendeids they obviously function as sensors for locating food (J.W.Hedgpeth, personal communication). The ovigers, which are peculiar to the Pycnogonida, comprise from four to ten segments. When present, their primary function in the male is the transportation of maturing egg masses. Within the genus Colossendeis, however, although the male possesses ovigers, they have not been observed to carry eggs, and development of the eggs remains a mystery. The secondary function of ovigers in both sexes, is that of grooming appendages, serving to remove epizoites and detritus adhering to the appendages. This is achieved by combing the appendage with the 'shepherd's crook' (the terminal four ovigeral segments). The walking legs are formed from eight segments in all species. There are three small proximal coxae, the second bearing the genital pore, a long femur, two long tibiae, a short tarsus and propodus, and, distal to the propodus, a well developed terminal claw. In some genera, a pair of auxiliary claws is also present.

Although there has been a great deal of research in recent years into the functional morphology of arthropod locomotion, especially by Manton (1950 - 1978), the Pycnogonida have received little attention.

Movement in pycnogonids may occur actively by walking or swimming, or passively by being carried with ocean currents whilst attached to hydroids or algae. The most common method of active locomotion consists of a slow walk. However, Cole (1901), Prell (1910), Knight-Jones & MacFadyen (1959) and Morgan (1971) have all reported the more gracile-like species to swim freely, using their walking legs to propel themselves through the water. The legs beat at right angles to the longitudinal axis of the body, with the result that the animal moves through the water dorsal side first (Morgan, 1971). Knight-Jones & MacFadyen (1959) have shown that during swimming the legs beat in metachronal rhythm, starting from the rear. Prell (1910) agrees, stating that the walking movement is more arhythmic than the swimming motion. There has also been one report of a pycnogonid, Nymphonella tapetis Ohshima, 1927, digging in sand (Arita, 1937). This contains the only record of the ovigers being employed to aid the walking legs in movement.

The nervous system of pycnogonids consists of a supra-oesophageal mass, or brain, which is connected by circum-oesophageal commissures to a chain of paired ventral ganglia. From the dorsal surface of the brain four optic nerves lead to the ocular tubercle, one to each eye (Henry, 1953). Nerves to the chelae arise from the front of the brain, together with a median rostral nerve and paired stomodaeal nerves which lead to the proboscis, where they are joined by ladder like connections at intervals along its entire length. The ventral ganglia correspond to the somites in number and position. Palpal and ovigeral nerves arise from the anterior of the first ventral ganglion, and each gangion supplies a pair of nerves to the ventral muscles of the somite, and two nerves to each leg. One nerve serves the dorsal part of the leg above the endosternite, the other the ventral section. The terminal trunk ganglion also supplies three paired nerves to the abdomen.

The digestive tract of pycnogonids consists of three distinct regions, a fore-, mid- and hindgut, separated by a tripartite valve. The Y-shaped trilobed mouth leads directly into a large sac or pharynx. This is approximately two-thirds the length of the proboscis and leads directly into the narrow 'oesophagus', which is Y-shaped in cross-section and extends into the cephalic somite. In the anterior region of the oesophagus are bases of numerous setae. These protrude forwards into the proximal region of the pharynx to form what is termed the 'oyster basket' sieve (Schlottke, 1933). The pharynx and oesophagus together form the foregut, and its junction with the midgut lies just posterior to the ocular tubercle.

The midgut, which extends through the rest of the trunk, possesses diverticula (caeca) which extend into the walking legs beyond the leg bases and, if chelae are present, into these also.

The junction of the midgut with the hindgut is at the distal end of the trunk, the hindgut extending through most of the length of the abdomen and opening to the exterior via a Y-shaped anus.

The chelae, when present, are used to tear off portions of food, for example hydranths, and force them into the mouth. When larger animals, such as actinians, are preyed upon the proboscis is thrust into the prey and the juices sucked out. Once in the pharynx, the food is filtered by the 'oyster basket' ensuring that only fine particles and fluid reach the midgut. The midgut is the site of digestive and absorptive processes. Digestion is intracellular. Proteases, carbohydrases, nucleases and acid and alkaline phosphatases have all been identified. Nutrient uptake is by means of micropinocytosis (Richards & Fry, 1978). Undigested material passes out through the hindgut to the exterior via the anus.

Food is passed along the entire length of the alimentary canal by a series of peristaltic waves produced by the musculature surrounding the gut.

Richards & Fry (1978) have observed the ability of some polar pycnogonids (Nymphon hirtipes from the Arctic and Nymphon orcadense and Nymphon australe from the Antarctic), to survive long periods - up to 18 months - without actively feeding and without evident adverse effects.

A number of authors, most recently Wyer (1972), have commented on the occurrence of pits within the pycnogonid cuticle, although Stephens (1972) doubts that arthropods can take up nutrients through their cuticles. The high surface to volume ratio, and cuticular pits of unknown function in pycnogonids, suggest that cuticular uptake of nutrients might possibly occur, and is worthy of investigation (Richards & Fry, 1978). Another possibility that might exist is the absorption of nutrients from the surrounding water through the intestinal wall (J.W.Hedgpeth, personal communication).

The circulatory system is open and the blood, or haemolymph, is similar to that found in other arthropods. It is blue in colour (Dawson, 1934) and functions both as a carrier of nutrients and respiratory gases. Circulation is achieved by a muscular dorsal vessel, or heart, situated within the cephalic somite, just ventral to the ocular tubercle. The body, together with the appendages, is divided by septa into a number of compartments or haemocoels. The largest of these is the endosternite, which lies horizontally in the trunk, between the heart and the gut, and above the gut in the appendages (Firstman, 1973). Within the region of the lateral processes the septum is perforated by slits, allowing the haemolymph to flow between the dorsal and ventral haemocoels. These, plus the possible muscular contraction of the septa, aid circulation. King (1973) has observed random rapid leg movements, and although it is not known whether these occur at times of respiratory stress, they could act as auxiliary pumps to aid circulation.

The absence of a coelom, which most workers believe has completely regressed, is accompanied by the absence of any discrete excretory organs, malpighian tubules or nephridia. This absence suggests that waste products are eliminated either from the gut, by the detachment of cells from the epithelium, or are passed out through the epidermis. It is possible, in forms which continue to moult during the adult stage, that both of these processes could contribute to excretion (Sanchez, 1959).

Pycnogonids have no discernible organs of respiration; however, because of their large surface to volume ratio, sufficient gaseous exchange can occur across the cuticle by means of diffusion (Manton, 1978), or even through the intestinal wall (J.W.Hedgpeth, personal communication).

The sexes are separate in all but one species of pycnogonid. The gonads lie on either side of the heart and, like the digestive system, each gonad sends lateral branches into the walking legs. The genital pores are located on the second coxal segment of some or all of the legs. King and Jarvis (1970) have shown that during early egg development the yolk is synthesized within the enlarging ova, in a pattern similar to that found in other aquatic chelicerates such as Limulus, there being little extra-oocytic contribution to the yolk formation.

In those species in which mating has been observed the male clings to the ventral surface of the female in such a way that the genital pores of each sex are aligned in a sort of pseudocopulation. The eggs are fertilized as they are released. In many pycnogonid species the spermatozoa are non-motile.

As the eggs are laid and fertilized the male gathers them, forming a ball that is carried on the ovigers until the young hatch. Some males have been observed carrying as many as fourteen egg masses, some newly collected, others in the process of hatching.

In some species the young hatch out as post-larvae, with four or

more pairs of appendages. In others, the young hatch as protonymphon larvae, with only three pairs of appendages. The protonymphon larva superficially resembles a barnacle nauplius except that it cannot swim. Further segments and additional legs are added at the posterior end as the larva develops into an adult. During development after hatching, juveniles grow by a series of moults, but adults may grow by a process not involving moulting (Jarvis & King, 1972).

The majority of pycnogonid research has concerned taxonomy. Despite this the classification remains unstable, with some major problems remaining unsolved. Two such problems which have hindered the development of a comprehensive classification of the group are, firstly, a taxonomic uncertainty as to where the pycnogonids fit within the Arthropoda, since they possess affinities with both the Crustacea and Arachnida, and secondly, the puzzling apparent metameric instability of the group. The occurrence of pentamerous forms, together with the lack of a detailed fossil record, has led to the suspicion that the group is evolutionarily very young and still undergoing rapid adaptive radiation.

The first problem is best summed up by Marcus (1940), " The Pantopoda (Pycnogonida) do not in any phase exhibit the crustacean biramous limbs or the arachnomorphous body composed of a cephalothorax (prosoma) with six pairs of appendages, and abdomen (opisthosoma). Therefore, it seems advisible to consider them as a separate class within the Arthropoda."

Manton (1978) believed that the pycnogonids are undisputedly evolved from chelicerate stock, perhaps from as far back as the very early paleozoic, when arachnid lines began to diverge. Non- chelicerate features, such as ovigers and multiple genital openings, evolved within the marine environment from an unknown early arachnid group as adaptations for survival in the sea. These features alone, however, are not sufficient to preclude the possibility of a pycnogonid/ arachnid

affinity.

Hedgpeth (1954) disagrees, believing that pycnogonids cannot be included within the Arachnida or Chelicerata, but should be recognized as an independent arthropod group. Indeed, he states " Certainly the sum of the morphological and developmental features in the Pycnogonida indicate that they cannot be affiliated with any other group."

The second major problem has also been clarified by Hedgpeth (1947; 1954 & 1978) and Bergström et. al.(1980), showing the group to possess a distinct fossil record, dating back to the Lower Devonian. Such an example is Paleoisopus problematicus Brolli, 1928 from the Hunsrück shale,Bavaria (fig 1.1).

The occurrence of a pentamerous fossil, Pentapaleopycnon inconspicua Hedgpeth, 1978, from the Jurassic period, is thought by Bergström et. al.(1980) to bear a greater resemblance to a phyllosoma larva. However, if it is a fossil pycnogonid it would indicate that the varying metameric nature of pycnogonids is not a recent phenomenon, but instead shows the group to have a long continuing adaptive radiation.

Snodgrass (1951) best sums up the situation by stating " It is immpossible to arrive at any positive conclusion concerning the relationships of pycnogonids, except that they are arthropods." Savory (1964) adds " Pycnogonids can justifiably be placed in a sub-phylum by themselves without the feeling that by doing so the problem of their affinities is merely being evaded."

Modern pycnogonid classification is unstable above the family level (Fry, 1978). The majority of the classification down to, and including, the family level is based upon the presence or absence of chelicera, palps and ovigers. However, there are so many transitional forms that family divisions are not always distinct, and therefore orders cannot be recognized.

The most recent and, at present, most widely used system of classification has been produced by Hedgpeth (1947; 1955). The Pycnogonida are divided into two orders, Pantopoda Gerstaecker, 1863, containing all extant species divided into eight families, and Paleopantopoda Brolli, 1930, containing all extinct forms found in the fossil record.

Hedgpeth (1947) also highlighted many of the problematical genera which were clouding family distinctions. However, this system, although a vast improvement on anything published previously relies on the presence or absence of the anterior appendages.

Fry (1978), in an attempt to produce a new workable classification of the group, took 45 external morphological characters for each of 73 extant genera and treated them withsome of the multivariate analyses developed over recent years to aid numerical taxonomy. The aim of this investigation was to produce a new classification within the framework of the Linnean hierarchy.

The results, which Fry himself treated not as an unravelling of pycnogonid phylogeny, but rather as an attempt to produce a primary hypothesis of degrees of overall morphological similarity, have yielded a scheme of classification involving thirty families in five orders.

Until such a hypothesis has been rigorously tested using existing biological and ecological data, and therefore verified, the regime of Hedgpeth (1947; 1955) must remain the definitive statement on the classification of pycnogonids.

The family Nymphonidae Wilson, 1881 (Hedgpeth, 1947) is composed of approximately 200 species in five genera. Heteronymphon Gordon, 1932 and the ten legged Pentanymphon Hodgson, 1904 are each represented by two species, Sexanymphon by one, Boreonymphon Sars,1891 was thought to be monospecific, but is now known to contain four species (Just, 1972), and Nymphon Fabricius, 1794 which contains the majority

of the species.

The genus Nymphon is the largest within the Pycnogonida. It is characterized by well developed, denticulate, two segmented chelate chelae, palps of five segments and ten segmented ovigers in both sexes, bearing a terminal spine. Although the genus reaches its greatest diversity in polar regions, temperate and tropical members are by no means rare. Within the Antarctic, the genus was last extensively studied by Gordon (1932), with eighteen species being recognized. However, a revision of the genus in this area is sorely needed, as very little research has been conducted since.

Species of the genus occurring in Arctic waters have attracted more attention than others in the genus, especially with regard to systematics. The majority of research was conducted with collections made during the great scientific expeditions of the late ninteenth and early twentieth centuries. However, much of the wealth of information produced during this period has subsequently proved to be of a contradictory nature. Indeed, Hedgpeth (1948) comments " the taxonomy of the genus Nymphon is in such a chaotic state that it is with some hesitation that I propose two new species".

In recent years, species of the genus from the Western (Canadian) Arctic have been the subject of some attention and, thanks to Hedgpeth (1948; 1963), many of the taxonomic anomalies surrounding the genus within that area have been clarified. The Eastern Arctic, however, where the genus appears to be at its greatest specific diversity and abundance, remains taxonomically in a state of disarray. Apart from Russian biologists (Nesis, 1960; Losina-Losinsky, 1961), who favour a different scheme oftaxonomy, Nymphon within this area has not been examined in detail since the work of Stephensen (1933; 1936; 1943). This revision has been occasioned by that deficiency.

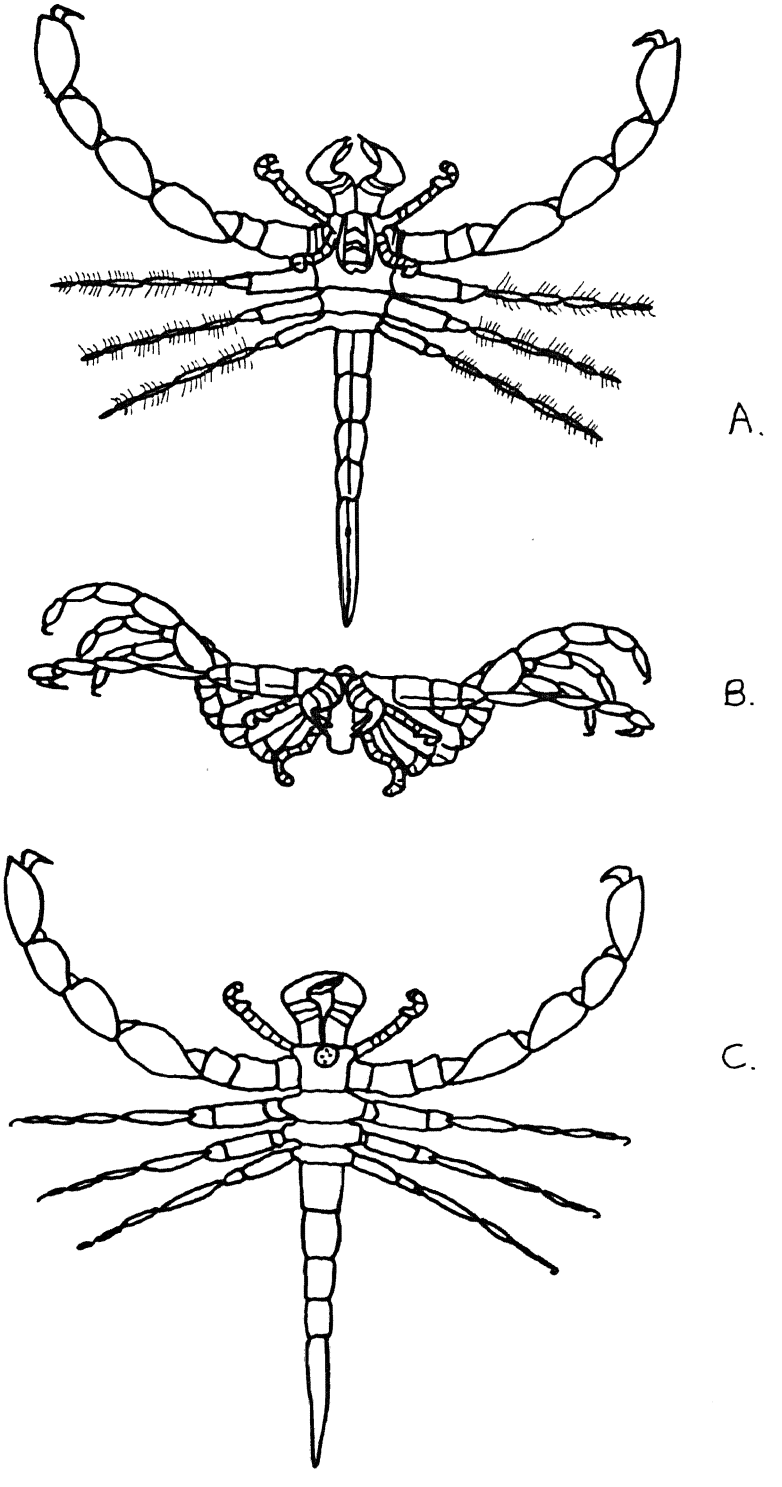
For practical purposes of this research the Eastern Arctic may be considered to be bounded on the west by the eastern coastline of

Greenland, and on the east by the coasts of the White and Kara seas. To the north it is bounded - for practical purposes of biological investigation - by the permanent ice-edge, while its southern boundary is partially defined, to the west of the British Isles, by the Greenland-Iceland and Iceland-Faroe ridges. Between the west coast of Scotland and the Faroes the southern boundary is breached by the Faroe channel, which reaches 1300-1400 metres in depth and is known to carry south to southwesterly flowing currents (Dietreich, 1969). To the east of the British Isles there is no definite topographical boundary, the depths shoaling gradually thoughout the entire northern North Sea. Nevertheless, for the purposes of this study, the latitude of 60°North has been taken as the southeastern boundary of the Eastern Arctic with the North Sea (Map 1.1).

Within this area, two major water types can be detected, a warmer, higher salinity type which flows into the region in a general northeasterly direction from the Atlantic, and a colder, lower salinity, water which moves in a general southwesterly direction, down from the ice-edge - its decreased temperature and salinity being due to ice melt during the summer months (Map 1.2).

The bathymetry of the area is also varied, including shallow (less than 400 metres) areas of continental shelf, which includes the entire Barents Sea, and areas of abyssal plains, such as the Norwegian and Greenland basins, which exceed depths of 3000 metres (Map 1.2).

Fig 1.1.

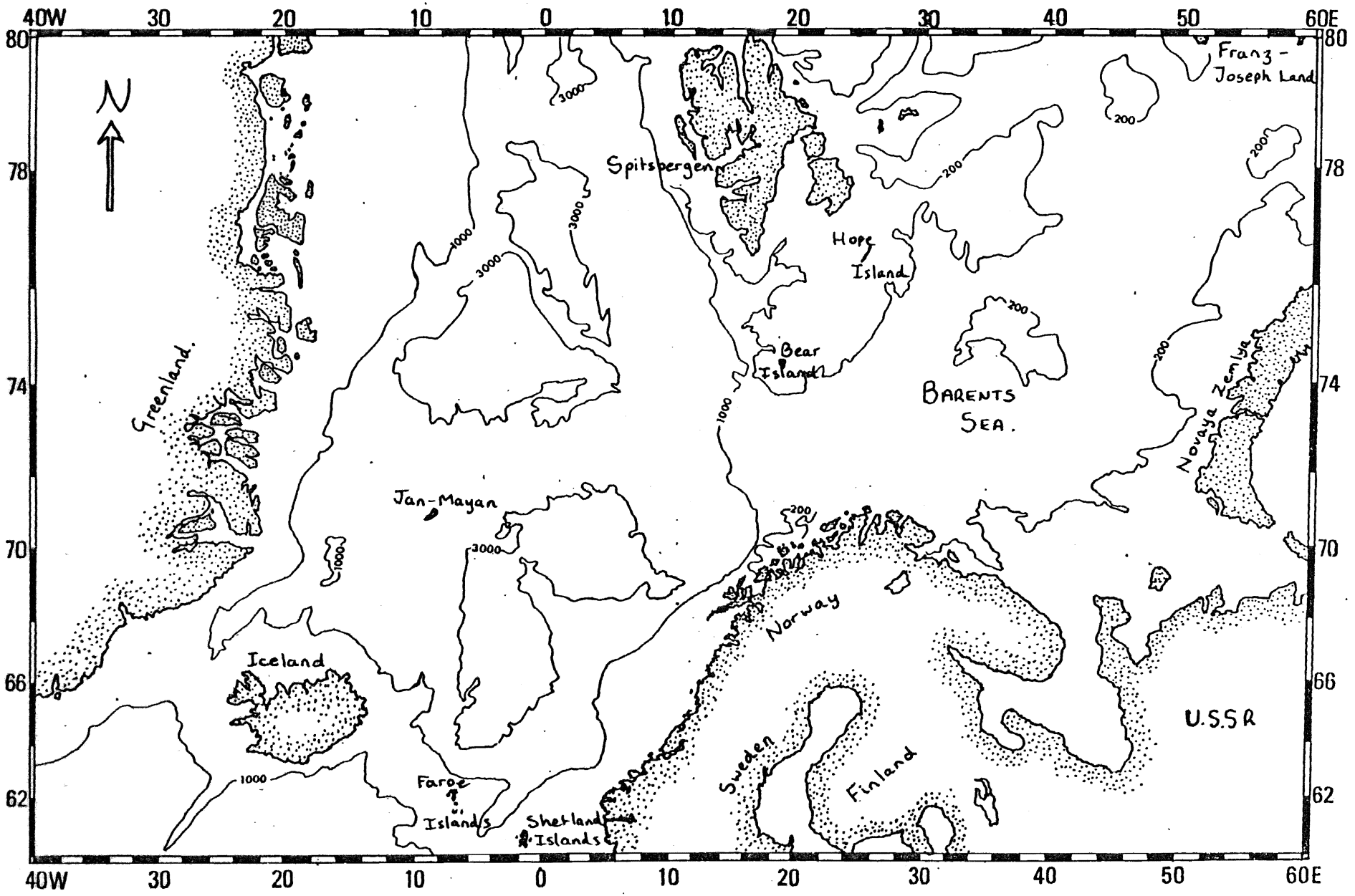


Reconstruction of Palaeoisopus problematicus

A, ventral; B. Frontal; C. Dorsal.

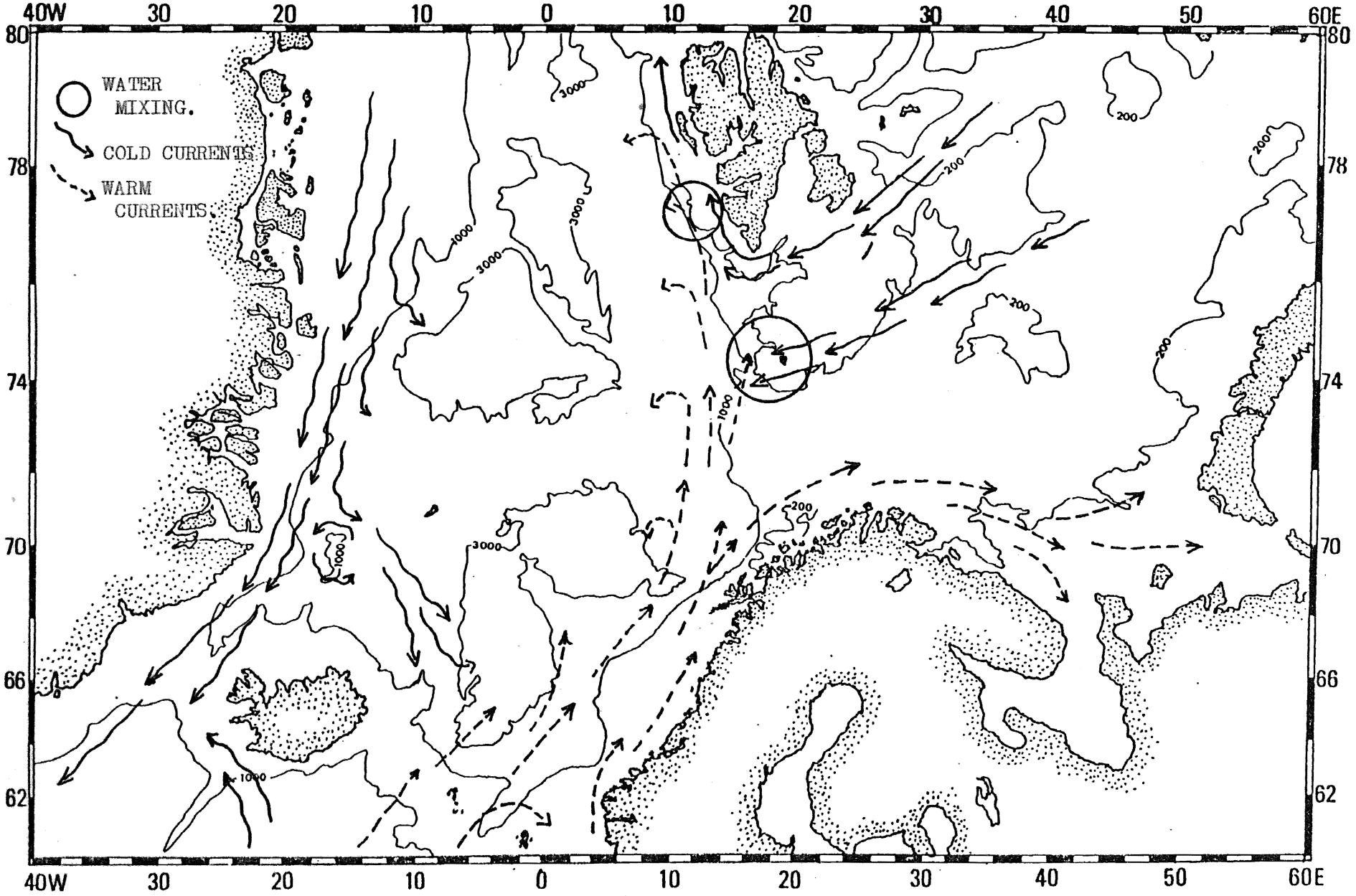
After Bergström et al (1980)

Map 1.1.



THE EASTERN ARCTIC.

Map 1.2. The Bathymetry and major surface currents within the Eastern Arctic.



2. TAXONOMY.

INTRODUCTION.

Systematically, the Eastern Arctic species of the genus Nymphon Fabricius, 1794, are in considerable disarray. Indeed, that is probably true of all 500-600 species of the genus so far described, and the literature undoubtedly contains many synonyms.

Within the Eastern Arctic, as defined in Section one, Sars (1888) attempted to subdivide the genus, separating the morphologically more robust and heavily setose species into a distinct genus, Chaetonymphon.

This scheme appeared to be successful within the Arctic fauna, where morphological distinctions between the two groups were very clear. However, within the Antarctic fauna, the separation between the two genera seemed to break down (Calman, 1915; Gordon, 1932).

Sars (1888) had also established the genus Boreonymphon to contain the single species Nymphon robustum Bell,1853, because of the non-dentate and arcuate chelae in this species. This subdivision has been questioned by several authors (Meinert,1899; Losina-Losinsky, 1935; Hedgpeth, 1963) but was not discussed in detail until Just (1972) revised the genus Boreonymphon, recognising the four species B.robustum (Bell,1853), B.abyssorium (Norman, 1873), B.compactum Knaben (1972) and B.ossiansarsii Just (1972).

Using a numerical taxonomic procedure, Fry (1978) tentatively concluded that Boreonymphon is more closely related to the Colossendeidae Hoek,1881, than to the Nymphonidae Wilson, 1887, but the validity of this inference still requires to be tested with a study as detailed as that of Just.

From the N.E. Atlantic collections examined during the present study and from reports in literature it seems that of the pycnogonid

genera Nymphon is the most diversified, reaching its greatest diversity within the Eastern Arctic region. As yet no complete life cycle has been observed for any Eastern Arctic Nymphon species and consequently the taxonomy has been based entirely on adult interspecific morphological differences. Additionally, the majority of Nymphon species are morphologically very similar, having much finer specific distinctions than are regarded as acceptable within other genera, for example, Colossendeis Jarzynsky, 1870. The exceptions are the species comprising the former genus Chaetonymphon, which do form a natural subgroup within the Eastern Arctic.

As a result of this homogeneity, many dubious poorly described species have entered the literature, with consequent hindering of taxonomic clarity.

In an attempt to resolve these problems, a literature review dating back to 1794 has been undertaken. Because of the variable quality of many of these descriptions and illustrations, collections were investigated including, where possible, type series of Eastern Arctic Nymphon species.

METHODS.

Figures were constructed using a Wild-Heerbrug M5 stereomicroscope with sliding stage and camera-lucida attachments. Single ovigeral spines were detached from the oviger, dehydrated in absolute alcohol, mounted in Euparal and drawn using a Reichert Visopan microscope.

A male bearing ovigeral egg-masses has been drawn for each species. The egg-masses are shown transparently allowing the ovigeral segments to be seen. Where sexual differences occur, the relevant female segments and appendages have also been drawn.

To aid species identification and comparison, a common format for figures and descriptions has been produced, with similar interspecific structures being drawn from similar aspects.

To aid the taxonomic and morphological studies within the Eastern Arctic Nymphon species a detailed taxonomic analysis has been undertaken, comprising the measurement of as many species as possible within the area.

To achieve statistical robustness each sample consisted of at least thirty specimens although, owing to the variable abundance of different species, this was not always possible.

Initially Nymphon hirtipes and N.strömi, the two most abundant species, were selected station by station (thirty animals for each station) from the whole known geographical range. In addition, the total available collections of N.elegans, N.grossipes, N.longimanum, N.longitarse, N.macronyx, N.megalops, N.serratum, N.sluiteri and N.tenellum were analysed.

Each specimen was numbered, sexed and measured using a Wild-Heerbrug M5 stereomicroscope fitted with sliding stage and eye-piece micrometer. Nineteen primary measurements (total twenty three) have been employed for the analysis (Table 2.1).

Where possible, the third left leg and left palp were measured in each specimen (c.f. Fry and Hedgpeth, 1969). Measurements of leg and palp segments and of body somites were made between the centre of the end of each joint. In the case of curved segments the measurement was taken as the chord of the arc and where distal segments have been measured (abdomen, proboscis and terminal claw) the measurement was taken from the centre of its proximal point to its farthest distal extremity (excluding setae).

Two computer programmes have been developed (Appendix IV) which enable the data to be input, filed and retrieved when required. A visual display input programme (V.D.4) has minimised manual error and when run in conjunction with the programme CHECK.1, allows for ammendment and checking of the data.

TABLE 2.1 MENSURAL VARIABLES.

NUMBER.	ASPECT.	DEFINITION.
0	-	Total leg length (13 + 17 + 22).
1	Dorsal	Trunk length.
2	Dorsal	Proboscis length.
3	Ectal	2nd palp segment length.
4	Ectal	3rd palp segment length.
5	Ectal	4th palp segment length.
6	Ectal	5th palp segment length.
7	-	Total palp length (3 + 4 + 5 + 6).
8	Dorsal	Cephalic somite length (midline from proboscis ridge to second somite).
9	Dorsal	Cephalic somite width (centre of lateral processes).
10	Posterio-lateral	1st coxal segment length.
11	Posterio-lateral	2nd coxal segment length.
12	Posterio-lateral	3rd coxal segment length.
13	-	Total coxal length(10 + 11 + 12).
14	Posterio-lateral	Femur length.
15	Posterio-lateral	1st tibia length.
16	Posterio-lateral	2nd tibia length.
17	-	Total length of central leg segments (14 + 15 + 16).
18	Posterio-lateral	Tarsus length.
19	Posterio-lateral	Propodus length.
20	Posterio-lateral	Terminal claw length.
21	-	Total length of terminal leg segments (18 + 19 + 20).
22	Posterio-lateral	Auxiliary claw length.
23	Ectal	Abdomen length.

The first palp segment was not measured because it is usually damaged during palp removal.

Two additional statistical programs (D.A4 & D.A6) have been written for hypothesis testing. D.A4 is a regression analysis program to aid the clarification of species descriptions. It calculates the first,second and third order regression equation coefficient values for selected pairs of measurement variables within selected groups of individuals (species sex or station).

The program also defines the suitability of fit of the first, second and third order regression equations by F-test assessments of improvements in residual variance and, in addition, calculates the sum of squares, variance, residual variance and product moment correlation coefficients (for first order only) for each pair of variables.

Program D.A6 enables the testing of biological differences (the basic hypothesis being that each sample is different), by taking two samples of paired individual variables and testing them by a modification of the D.A4 statistical routine.

The two samples are pooled and analysed to find if the residual variance about the regression line which fits the pooled data is statistically greater than the sum of the residual variances about the regression lines of the two separate samples.

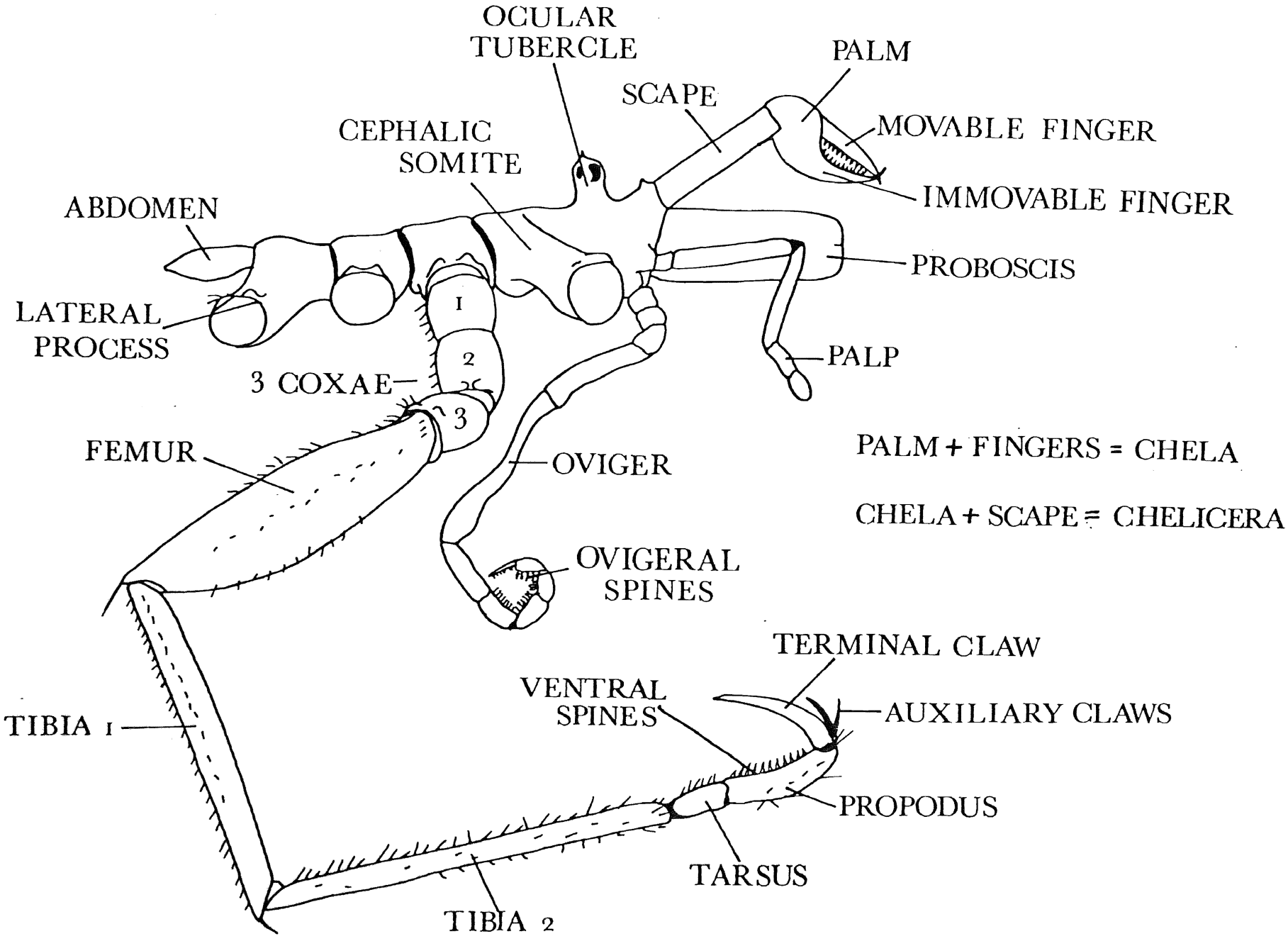
The program enables sexual, seasonal and regional intraspecific differences to be investigated, as well as allowing for testing of statistically significant interspecific differences.

EXPLANATION OF DESCRIPTIONS AND FIGURES.

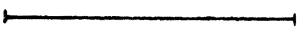
Past authors have used a variety of terms to denote the structure of pycnogonids. The terminology used here is that of Hedgpeth (1948) and Fry & Hedgpeth(1969), (fig 2.1).

FIGURE 2.1.

Lateral view of an "ideal" pycnogonid, illustrating the terms used throughout this study.


OCULAR TUBERCLE
PALM
SCAPE
MOVABLE FINGER
CEPHALIC SOMITE
IMMOVABLE FINGER
ABDOMEN
PROBOSCIS
LATERAL PROCESS
1
2
3 COXAE
3
PALP
FEMUR
OVIGER
PALM + FINGERS = CHELA
CHELA + SCAPE = CHELICERA
OVIGERAL SPINES
TERMINAL CLAW
VENTRAL SPINES
AUXILIARY CLAWS
TIBIA 1
PROPODUS
TARSUS
TIBIA 2

Within the systematic section, scales are represented in the following scheme :-



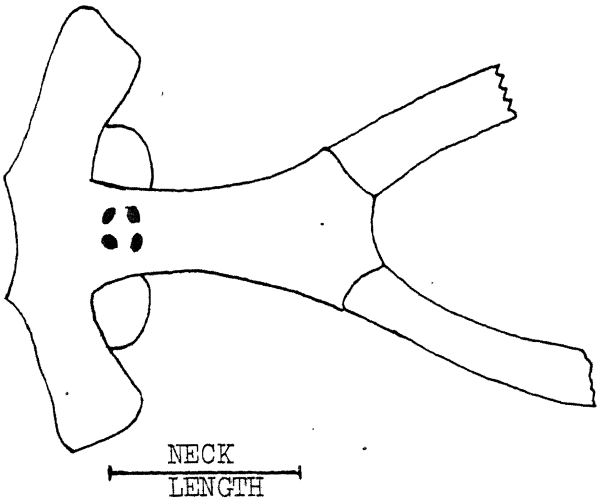
A B D F = 2mm.
C E G = 1mm.

This indicates that for structures A,B,D and F the line scale represents two millimetres, and for structures C,E and G, one millimetre.

Where relative segment lengths and setation have been described, the terms subequal (≐) and uniform indicate that the smaller value is not less than 70% of the larger (c.f., Fry & Hedgpeth, 1969).

TRUNK. Lateral processes and the neck have been described from a dorsal aspect. Neck measurement* was made from the anterior edge of the first lateral processes to the position where the cephalic somite widens to accomodate the scape insertions (fig 2.2).

Fig 2.2.



The three types of ocular tubercle found within Nymphon were described from an anterior aspect. Fig 2.3a shows the conical type, fig 2.3b the cylindrical type with dorsolateral processes and fig 2.3c, the cylindrical type with a domed crown and dorsolateral processes.

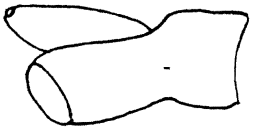
* It is difficult to measure this accurately, approximations, however are sufficient for species determination.

Fig 2.3a.

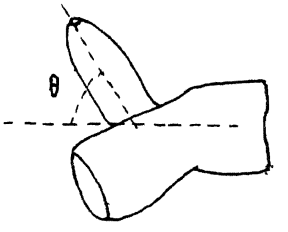
Fig 2.3b.

Fig 2.3c.

ABDOMEN. This has been described from a dorsal aspect. The angle between the lateral midline of the trunk and the midline of the abdomen has been used to describe the posture of the abdomen (fig 2.4)



HORIZONTAL



ANGLED.

Fig 2.4.

PROBOSCIS. Described from a dorsal aspect, following the scheme produced by Fry and Hedgpeth (1969), (fig 2.5). Three types occur within the Eastern Arctic Nymphon species:- A', B"' & J'.

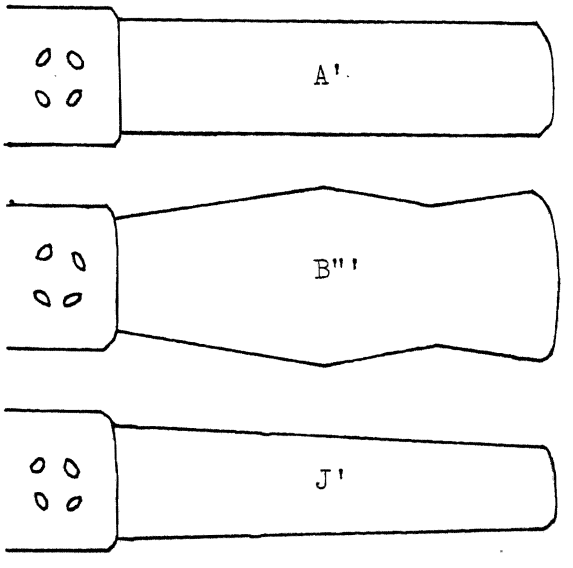


Fig 2.5.

PALPS. These have been described from an ectal aspect. The formulae used to describe palp, oviger and coxae relative segment lengths are written in the following form :-

$$3 < 1 \simeq 2 = 0.5 \times 4 \simeq 5.$$

This example indicates that segments one and two are subequal in length, greater than the third segment length and ca half the length of the fourth and fifth segments, which are subequal. In all cases the formulae read from the shortest segment to the longest.

OVIGERS. The adult oviger only has been described. The ovigeral spine formulae refer to the denticular spination on the ventral edge of the terminal four segments, which in Nymphon is always segments seven to ten.

$$\frac{8-9}{7} : \frac{7-8}{8} : \frac{5-6}{9} : \frac{7-8}{10} + S.$$

The upper values indicate the ranges of spine numbers on the respective segments shown in the lower entry. The 'S' at the end of the formula indicates the presence of a terminal spine.

CHELICERAE. The scape has been described from a dorsal aspect and the chelae from a lateral aspect. The chelae are, however, usually carried turned inwards and upwards. There are two types of finger ending present in Eastern Arctic Nymphon species, oxeote (fig 2.6a) and tylote (fig 2.6b).

Fig 2.6a.

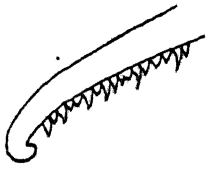
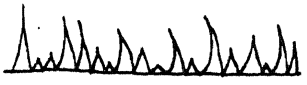


Fig 2.6b.

There are two forms of finger dentition, uniform needle (fig 2.7a) and mixed needle and peg (fig 2.7b). When dentition size, shape and pattern are identical for the two fingers it is referred to as being uniform.

Fig 2.7a.

Fig 2.7b.



LEGS. The third left leg has been described from a posterio-lateral aspect. General leg setation is given for all species but details of segmental setation is described only for the most heavily setose species.

DISTRIBUTION. This is divided into two sections for each species. The first gives the distribution within the Eastern Arctic, including a map of available cruise data. The second gives the overall distribution including the extremes of range and depth.

REMARKS. This section contains additional information concerning morphological points of interest and past taxonomic problems. To aid clarification of existing taxonomic problems, graphs of heterogonic growth pattens with explanations have been included.

KEY TO THE EASTERN ARCTIC NYMPHON SPECIES.

Genus Nymphon J.C.Fabricius, 1794.

(including Chaetonymphon G.O.Sars, 1891).

Chelicerae 2-jointed, chelate, chelae well developed. Palps 5-jointed. Ovigers present in both sexes, 10-jointed, terminal segments with denticulate spines and a terminal spine on the last segment. Body segmented, usually elongate but never tightly compact. Propodus without heel but usually with auxiliary claws.

1a Dorsal trunk surface and tibiae heavily beset with setae.....2.

1b Trunk and tibiae either sparsely or non-setose.....6.

2a Maximum tibial seta length > 0.5 x maximum segment diameter.....3.

2b Maximum tibial seta length ≤ 0.5 x maximum segment diameter.....N.hirtum.

3a Auxiliary claw length < 0.5 x terminal claw length.....4.

3b Auxiliary claw length > 0.5 x terminal claw length.....5.

4a Tarsus length ca 0.5 x propodus length.....N.macronyx.

4b Tarsus length ca 0.33 x propodus length.....N.hirtipes.

5a Distance between lateral processes ≥ 0.5 x distal diameter of lateral processes.....N.tenellum (robust morph).

5b Distance between lateral processes < 0.5 x distal diameter of lateral processes.....N.tenellum (graceful morph).

6a Ocular tubercle conical from anterior aspect.....7.

6b Ocular tubercle essentially cylindrical with two dorsolateral processes from anterior aspect.....9.

7a Terminal claw length > 0.5 x propodus length.....8.

7b Terminal claw length < 0.5 x propodus length....N.microrhynchum.

8a Terminal claw length > 0.75 x propodus length, auxiliary claw < 0.33 x terminal claw length.....*N.sluiteri*.

8b Terminal claw length ≤ 0.75 x propodus length, auxiliary claw > 0.33 x terminal claw length.....*N.grossipes*.

9a Chela dentition ununiform.....10.

9b Chela dentition uniform.....11.

10a Both fingers with oxeote ends.....*N.macrum*.

10b Movable finger with tylote ends.....*N.elegans*.

11a Both fingers bearing similar dentition.....12.

11b Immovable finger dentition *ca* 2.0 x length of movable finger dentition.....*N.strömi*.

12a Abdomen horizontal in lateral aspect.....13.

12b Abdomen angled in lateral aspect.....14.

13a Dorsoventral backward pointing projections present on trunk somites one to three.....*N.serratum*.

13b Somites one to three lacking projections.....*N.megalops*.

14a Tarsus length < 1.5 x propodus length.....15.

14b Tarsus length > 1.5 x propodus length.....*N.longitarse*.

15a Auxiliary claw length *ca* 0.25 terminal claw length.....*N.leptocheles*.

15b Auxiliary claw length < 0.25 x terminal claw length.....*N.longimanum*.

Nymphon elegans Hansen, 1887.

Nymphon elegans Hansen, 1887: 165, Pl 18, Fig 4; Sars, 1888: 349, No 26; 1891: 86, Pl 9, Figs 1a-g; Carpenter, 1898: 42; Möbius, 1901: 47; Norman, 1908: 215; Appellöf, 1910: 6; Stephensen, 1912: 585; 1913: 394; Schimkewitsch, 1930: 487, Figs 136-141; Stephensen, 1933: 17; Losina-Losinsky, 1935: 22, Fig 1; Stephensen, 1936: 21; 1943: 24; Hedgpeth, 1943: 86; 1948: 181; 1963: 1332.

Nymphon gracilipes; Sars, 1877: 256.

Material examined (See Appendix I).

Description. (fig 2.8)

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by 1.5 - 2.0 x their proximal diameter. Neck cylindrical, length ca 2.0 - 3.0 x diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound sited ca mid point of neck. Abdomen pyriform. Posture 60° from horizontal.

Proboscis length ca 0.8 x length of cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th very elongate-ovate. Relative segment lengths :- $1 < 5 = 0.5 \times 3 < 2$. Setation, 1st absent, 2nd and 3rd sparse distally, 4th sparse ventrally and distally, 5th heavy uniform.

Adult ovigers. Relative segment lengths :- $8 \triangleq 9 \triangleq 10 < 1 \triangleq 2 \triangleq 3 < 7 < 6 < 4 < 5$. In female, segment 6 length ca 0.33 x length segment 5. In male, segment 6 length ca 0.25 x length segment 5.

Ovigeral spine formula :- $\frac{22-24}{7} : \frac{19-20}{8} : \frac{17-19}{9} : \frac{17-20}{10} + S.$

Chelicerae. Scape essentially cylindrical, length ca 0.75 x length of chela. Palm essentially cylindrical, non-setose, length subequal with slender fingers. Fingers, non-setose, subequal in length. Movable finger with tylote end, immovable finger with gently tapering oxeote end. Dentition uneven, mixed needle and peg shaped teeth, separated distally by ca 0.25 x basal width. Immovable, 55 - 70. Movable 80 - 90.

Legs. Generally sparsely microsetose. Relative coxal lengths :- 1 ≏ 3 = 0.25 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length, ca 0.66 x length tibia 2. Propodus length ca 0.75 x tarsus length. Both armed with ventral spines, tarsus ca 35, propodus ca 40. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.33 x terminal claw length.

Size ranges. (table 2.2).

Distribution.

Eastern Arctic. (Map 2.1). Widespread throughout the region, locally common, particularly in the Faroe Channel, southern Barents Sea and Bear Island. Also recorded from Franz-Joseph Land, Jan Mayan and Norwegian Greenland and West Spitsbergen coasts. Depth range from 200-500 metres. Although rarely found below 600 metres it has been recorded to depths of 1358 metres (Mobius, 1901).

General. According to Hedgpeth(1963) " While not too common, this species has a wide distribution from across Russia to 80°E , and in the west to Repulse Bay (66.23N 86.12W)." It has also been recorded around Greenland (Stephensen, 1933) and the Kara Sea (Hansen, 1887).

Remarks. This species was originally classified by Sars (1877) as Nymphon gracilipes Heller (1875),(= N.strömi Krøyer, 1844), until

redescribed by Hansen (1887) to form a distinct species. Nymphon elegans is the only species within the Eastern Arctic to possess a tylote ending to the movable finger of the chela. According to Appellöf (1916) a confusion can arise between juvenile specimens of N.elegans and N.macrum, when the tylote ending has not fully developed.

Table 2.2 Nymphon elegans, size ranges, (in millimetres).

	MALE	FEMALE	JUVENILE
Trunk	4.96 - 5.28	4.32 - 6.40	4.32 - 5.00
Proboscis	2.72 - 2.80	2.24 - 2.88	1.92 - 2.40
Abdomen	0.48 - 0.64	0.64 - 0.96	0.32 - 0.80
Cephalic somite length	2.40 - 2.72	2.08 - 2.30	1.92 - 2.56
Cephalic somite width	2.40 - 2.88	2.08 - 3.04	1.92 - 2.56
Oviger.4	2.28 - 2.51	1.67 - 2.20	
Oviger.5	4.41 - 4.67	2.17 - 3.04	
Oviger.6	1.44 - 1.52	0.84 - 1.14	
Total palp	5.36 - 7.28	4.96 - 8.08	4.96 - 5.20
Coxa.1	0.80 - 0.96	0.80 - 1.12	0.80 - 0.88
Coxa.2	2.40 - 3.36	2.56 - 3.20	2.44 - 2.56
Coxa.3	0.96 - 1.12	0.96 - 1.44	0.80 - 0.96
Femur	6.88 - 8.16	6.56 - 8.96	5.60 - 6.72
Tibia.1	8.00 - 10.24	7.52 - 11.20	6.56 - 8.48
Tibia.2	12.96 - 16.48	12.00 - 17.12	10.40 - 13.12
Tarsus	1.60 - 2.80	1.44 - 2.24	0.50 - 1.44
Propodus	1.28 - 2.08	1.28 - 1.76	1.12 - 1.76
Terminal claw	0.66 - 0.72	0.56 - 0.96	0.40 - 0.48
Auxiliary claw	0.23 - 0.26	0.15 - 0.26	0.16 - 0.20

Fig 2.8. *Nymphon elegans*.

A. Trunk, dorsal view.

B. Trunk, lateral view (male with egg masses).

C. Female oviger.

D. Oviger, terminal segments.

E. Ocular tubercle, anterior view.

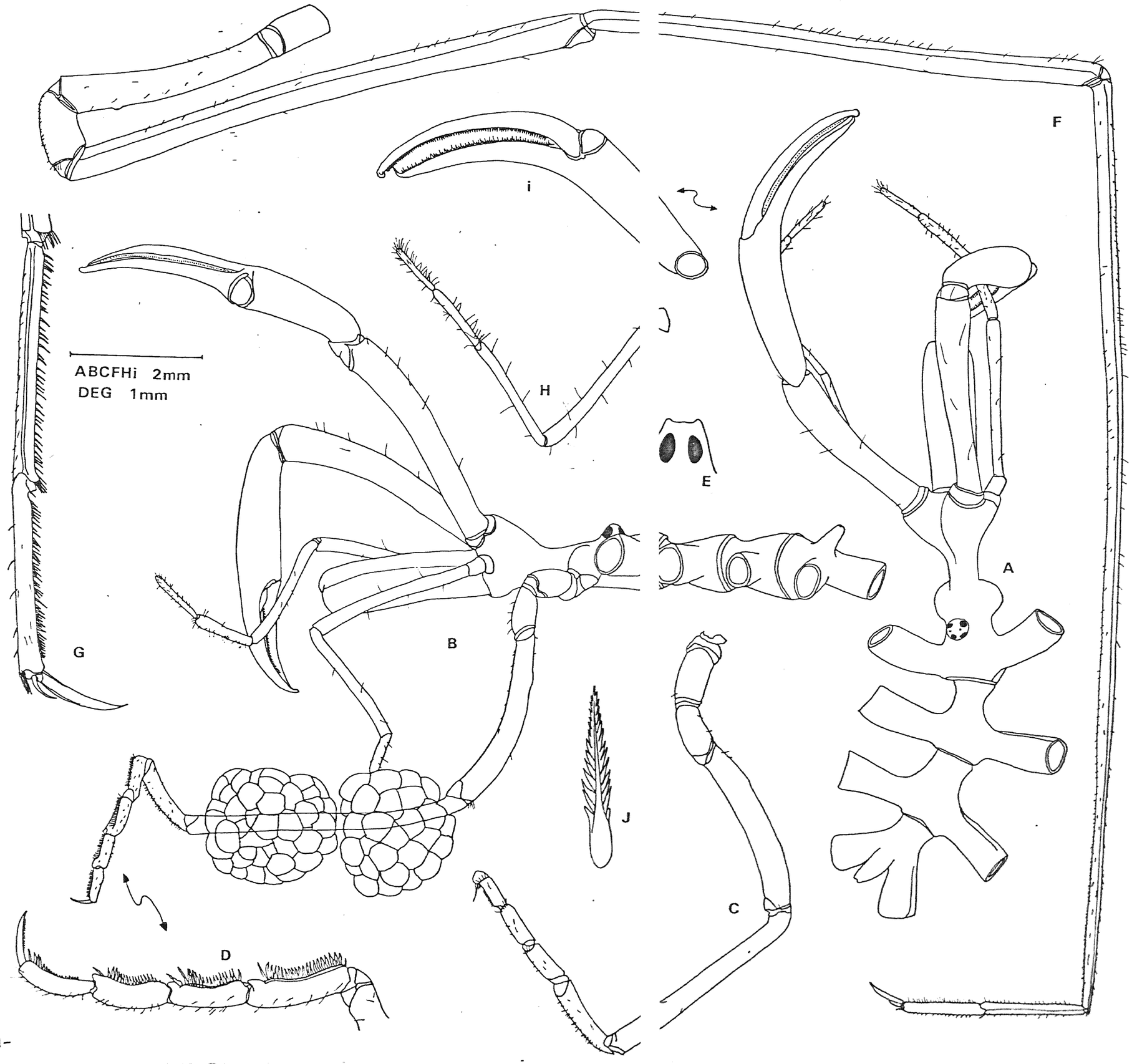
F. Walking leg.

G. Walking leg, terminal segments.

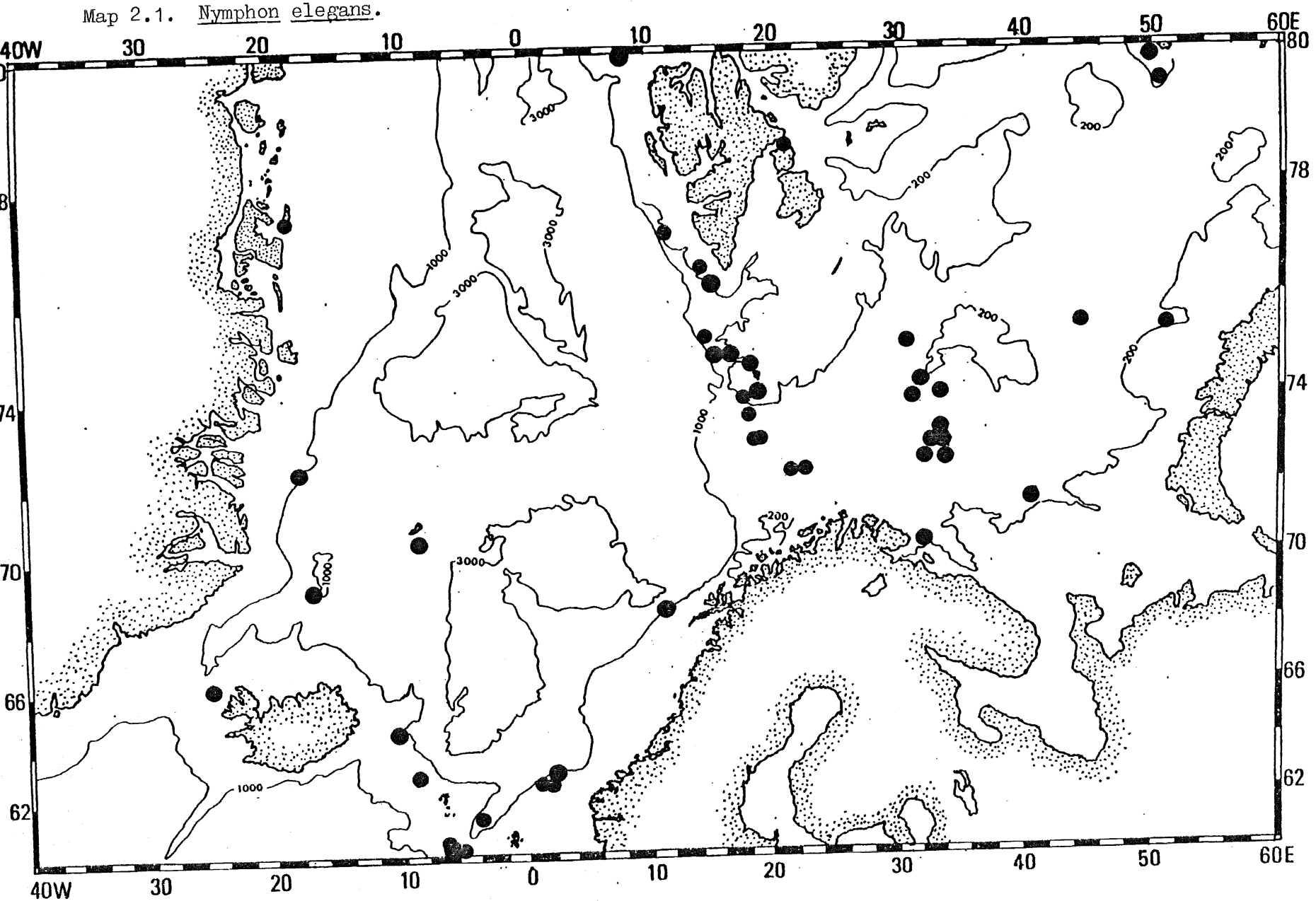
H. Palp.

I. Chela.

J. Ovigeral spine.


ABCFHi 2mm
DEG 1mm
A
B
C
D
E
F
G
H
i
J

Map 2.1. Nymphon elegans.



Nymphon grossipes (Fabricius.O) 1794.

Nymphon grossipes; Kroyer, 1844: 108; 1849: Pl 36, Figs 1a-h; Stimpson, 1853: 38; Verril, 1874: 411; Wilson, 1880:491, Pl 6, Figs 32-37; 1881: 253; Hoek,1881: 12, Pl 1, Figs 17-21; Hansen, 1886: 170, Pl 18, Figs 8-8a; Sars, 1891: 65, Pl 6, Figs 2a-i; Carpenter,1898: 629; Meinert, 1899: 35; Möbius, 1901: 42; Norman, 1908: 211; Appellöf, 1910: 3; Stephensen, 1913: 388; Appellöf, 1916: 13; Bouvier,1923: 28; Schimkewitsch, 1930: 400, Figs 101-112; Stephensen, 1933: 11; 1937: 3; 1943: 18, Fig 6; Hedgpeth, 1943: 85; 1948: 187; 1949: 249; Nesis, 1960: 142; Losina-Losinky, 1961: 69; Hedgpeth, 1963: 1329.

Pycnogonum grossipes Fabricius.O, 1794: 229, No 210.

Nymphon glaciale Liljeborg, 1851: Vol 7, 331; Sars, 1891: 63, Pl 6, Figs 1a-g; Norman, 1908: 211; Schimkewitsch, 1930: 421, Figs 110-112; Giltay, 1942: 459.

Nymphon mixtum Krøyer , 1844: 110; 1849: 35, Figs 1-2; Hansen, 1886: 128, Pl 7, Fig 19; Sars, 1891: 68, Pl 6, Figs 3a-i; Norman, 1908: 210; Ohshima, 1936: 862; Stephensen, 1936: 11; Nesis, 1960: 143; Losina-Losinsky, 1961: 70.

Nymphon piliferum Carpenter, 1898: 628, Pl 46, Figs 1-13.

Nymphon johnstoni Goodsir, 1842: 136.

Nymphon similis Goodsir, 1842: 136.

Nymphon turritum Exline, 1936: 416, Figs 33g-k.

Nymphon heterospinum Hedgpeth, 1949: 259, Fig 27.

Material examined. (See Appendix I).

Description (Fig 2.9).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 0.75 - 1.25 x their

proximal diameter, sparsely microsetose. Neck cylindrical, length ca 2.0 x diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, conical, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform, very sparsely setose dorsally. Posture, 75° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'

Palps. 1st - 4th essentially cylindrical, 5th conical. Relative segment lengths :- $1 < 4 \triangleq 5 < 2 < 3$. Setation, 1st absent, 2nd and 3rd very sparse, 4th and 5th uniformly microsetose.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$.

In femle, segment 6 length ca 0.4 x length of segments 4 and 5.

In male, segment 6 length ca o.2 x length of segments 4 and 5.

Ovigeral spine formula :- $\frac{17\text{-}18}{.7} : \frac{15\text{-}16}{8} : \frac{14\text{-}15}{9} : \frac{15\text{-}16}{10}$ +S.

Chelicerae. Scape essentially cylindrical, sparsely setose, length ca 1.25 x chela length. Palm essentially cylindrical, sparsely setose above movable finger, length ca 1.2 length of stout subequal fingers. Base of immovable finger with tuft of microsetae, movable finger non-setose. Fingers with oxeote ends. Dentition uniform, needle shaped, tightly packed. Both fingers possessing 25 - 35 teeth.

Legs. Sparsely setose. Relative coxal lengths :- In male $1 \triangleq 3 = 0.33 \times 2$. In female $1 \triangleq 3 = o.5 \times 2$. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 lengths subequal, ca 0.7 x length of tibia 2. Propodus length ca 0.7 - 0.8 x tarsal length. Propodus armed with 6 - 8 ventral spines, longest sited proximally. Terminal claw length ca 0.66 x propodus length. Auxiliary claw length ca 0.33 - 0.5 x terminal claw length.

Size ranges. (table 2.3).

Distribution.

Eastern Arctic. (Map 2.2.). Abundant and widespread throughout the whole area. Records range from the Faroes, Iceland, West Spitsbergen and the southern Barents Sea. Although few records exist for Norwegian waters, Sars (1891) states that the species is common along the entire coast. The species is common between 20 and 200 metres depth, it is rarely found below 600 metres although it has been recorded at depths of 1200 metres.

General. N.grossipes is widespread and, according to Hedgpeth (1963), is the most ubiquitous pycnogonid of the northern hemisphere. It has a southern distribution to Northumberland in the North Sea, Long Island Sound in the Atlantic and Puget Sound on the Pacific side.

Remarks. Not only is this species the most ubiquitous pycnogonid but also one of the most variable morphologically. Because of this great variation, Norman (1908) and Stephensen (1933) consider that N.mixtum and N.glaciale are specifically indistinct from it.

The greatest morphological variations occur in the length of the tarsal segment of the walking leg and the length and width of the cephalic somite. Graphs 2.1 and 2.2 represent the relationship between the lengths of the tarsus and total leg, and the length and width of the cephalic somite respectively. In both graphs (●) are specimens which have definitely been identified as N.grossipes whilst (▲) represent specimens of N.mixtum, N.glaciale and N.piliferum. Whilst both graphs confirm that leg segments and trunk somite size may vary considerably, correlation coefficients of 0.78 and 0.67 respectively show that the overall similarity of the species examined is sufficient to classify them within a single specific epithet.

There is some doubt as to whether Fabricius' description was of

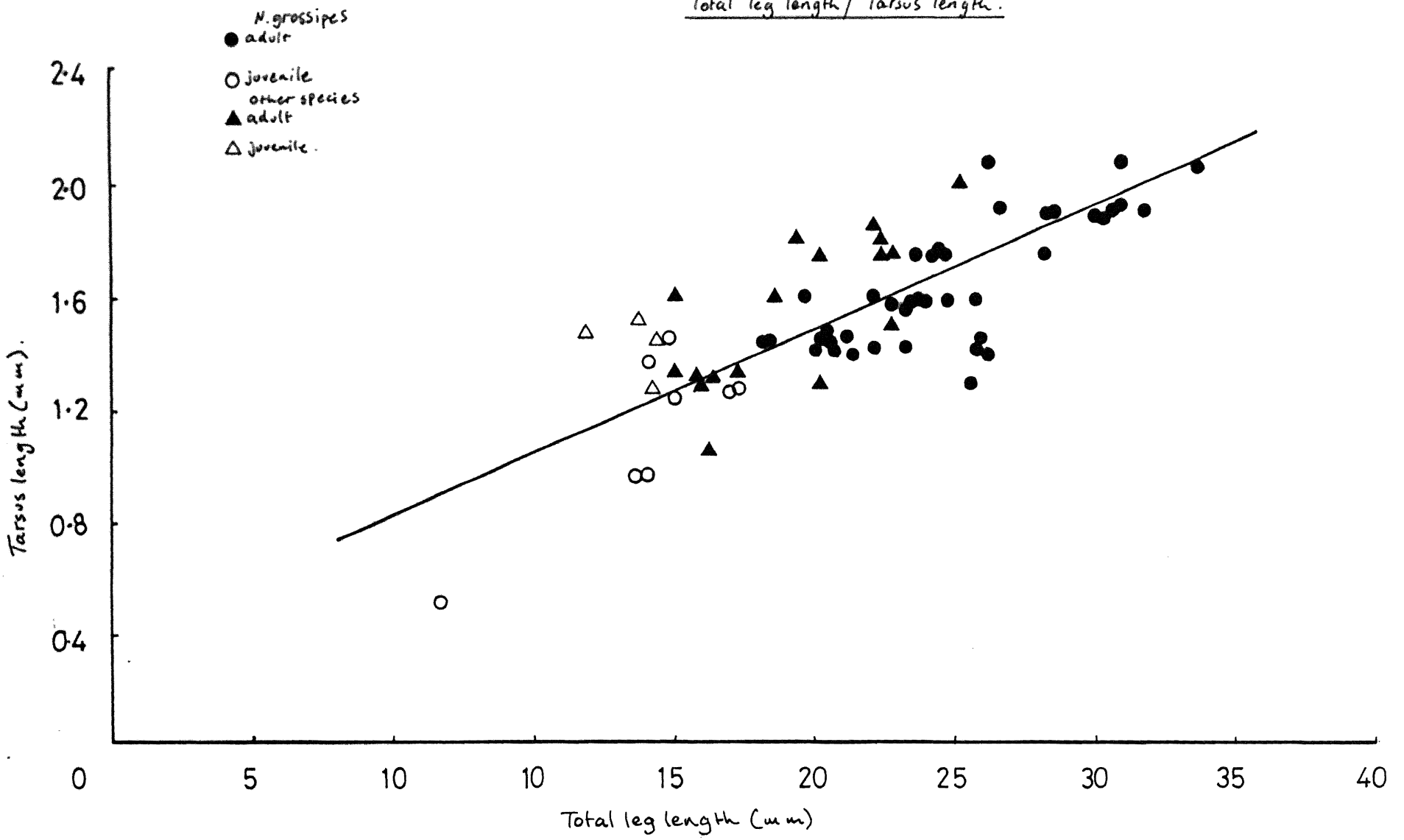
this species. Norman (1908) thinks it could be of N.mixtum whilst Krøyer (1844) believes that it might be of N.strömi. Stephensen (1933) states that the first valid description of this species in the literature is given by Krøyer (1844).

Table 2.3 Nymphon grossipes, size ranges. (In millimetres).

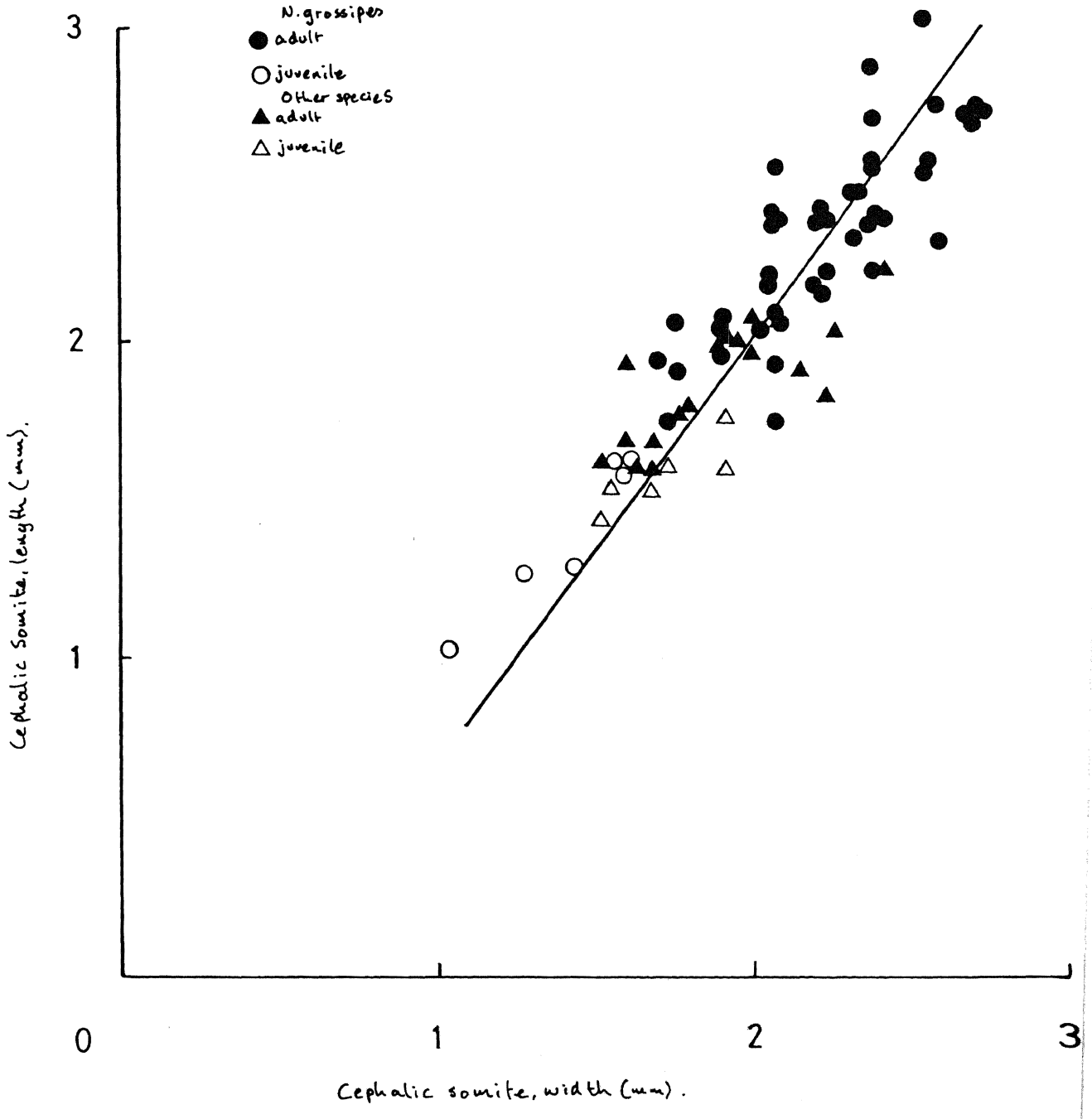
	MALE	FEMALE	JUVENILE
Trunk	3.20 - 4.55	3.28 - 5.60	2.08 - 3.07
Proboscis	1.20 - 2.21	1.32 - 2.40	0.91 - 1.95
Àbdomen	0.45 - 0.65	0.32 - 0.56	0.26 - 0.52
Total palp	1.72 - 3.77	1.72 - 2.88	1.47 - 2.73
Cephalic somite length	1.68 - 2.73	1.60 - 2.72	1.04 - 2.21
Cephalic somite width	1.60 - 2.60	1.52 - 2.72	1.04 - 2.21.
Oviger.4	2.88 - 4.10	1.82 - 3.04	
Oviger.5	2.75 - 4.10	1.75 - 2.96	
Oviger.6	0.84 - 1.44	1.06 - 1.40	
Coxa.1	0.64 - 1.04	0.80 - 0.12	0.39 - 0.78
Coxa.2	1.20 - 3.38	1.36 - 2.40	0.78 - 2.74
Coxa.3	0.72 - 1.04	0.80 - 1.60	0.39 - 0.78
Femur	4.00 - 6.50	4.24 - 7.20	2.34 - 5.76
Tibia.1	4.24 - 7.93	4.40 - 7.84	2.34 - 6.50
Tibia.2	5.44 - 11.83	6.16 - 11.52	3.64 - 9.75
Tarsus	1.44 - 1.95	1.44 - 1.92	0.52 - 1.96
Propodus	1.04 - 1.30	0.88 - 1.60	0.78 - 1.30
Terminal claw	0.64 - 0.88	0.64 - 0.84	0.39 - 0.52
Auxiliary claw	0.24 - 0.39	0.28 - 0.40	0.13 - 0.26

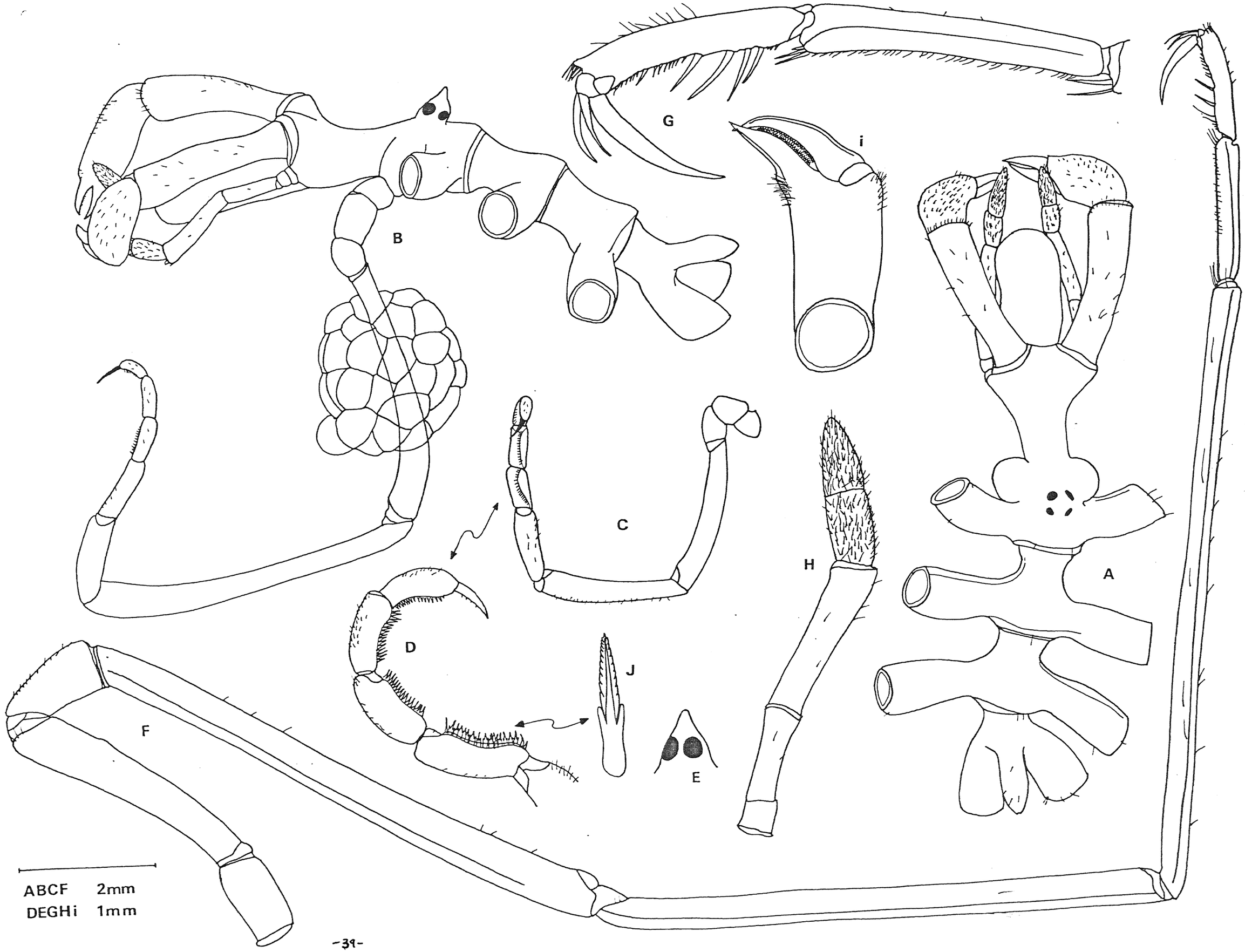
GRAPH 2:1. COMPARISON OF NYMPHON GROSSIPES WITH RELATED SPECIES.

Total leg length / Tarsus length.



GRAPH. 2.2. Comparison of N. grossipes with related species.
Cephalic somite width/length.




G
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H
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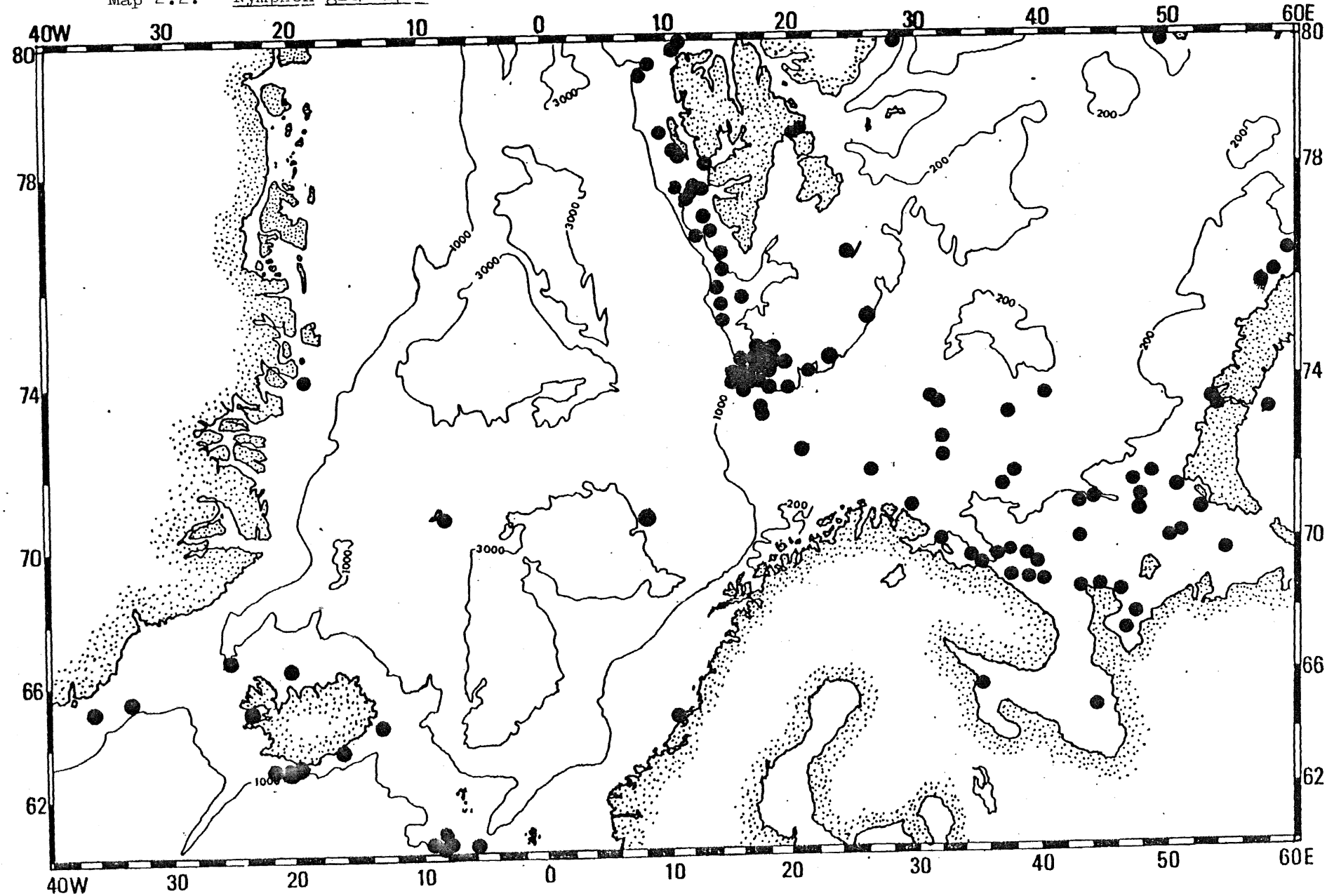
J
E
F
ABCF 2mm
DEGHi 1mm

Map 2.2. Nymphon grossipes.



Nymphon hirtipes Bell, 1853.

Nymphon hirtipes Bell, 1853: 403, Pl 35, Fig 3; Wison, 1878: 22, Pl 5, Figs 2-3; Hoek, 1882: 689, Pl 1, Figs 1-8; Hansen, 1887: 159; Hedgpeth, 1948: 183, Figs 10, 11b; 1963: 1326.

Chaetonymphon hirtipes; Sars, 1888: 353, No 33; 1891: 103, Pl 11, Figs 2a-k; Carpenter, 1898: 631; Norman, 1908: 219; Stephensen, 1913: 399; 1933: 8, Fig 2; 1937: 3 ; 1943: 8.

Nymphon spinosum; Meinert, 1899: 44, (partim).

Chaetonymphon spinosum; Möbius, 1901: 48, (partim); Schimkewitsch, 1930: 335, Figs 81-87, (partim).

Nymphon (Chaetonymphon) spinosum var hirtipes; Appellöf, 1910: 4; 1916: 6.

Nymphon spinosum var hirtipes; Losina-Losinsky, 1935: 17; Nesis, 1960: 139.

nec Nymphon spinosum Goodsir, 1842: 139, Pl 3, Fig 3, = N.hirtum Fabricius, 1794.

Material examined. (See Appendix I).

Description (Fig 2.10).

Trunk. Three complete intersegmental articulations, somites 1 - 3 armed with comb of dorsoposterior setae. Lateral processes essentially cylindrical, separated by ca 0.2 x their proximal diameter, lacking tubercles, armed with dorsodistal comb of setae. Neck indistinct. Centre of occular tubercle situated at anterior margin of 1st lateral processes, prominent, backward pointing, cylindrical with domed crown, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process and posterior of cephalic lobe. Abdomen pyriform, dorsally microsetose. Posture, horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE A'.

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- 1 < 5 < 4 < 3 < 2. Setation, 1st absent, 2nd sparse, 3rd, 4th and 5th uniformly heavy. Maximum seta length ca 1.5 - 2.0 x maximum segment diameter.

Adult oviger. Relative segment lengths :- 1 ≏ 2 ≏ 3 ≏ 7 ≏ 8 ≏ 9 ≏ 10 < 6 < 4 ≏ 5. In female, segment 6 length ca 0.75 x length segment 5. In male, segment 6 length ca 0.5 x length segment 5. In male 5th segment heavily setose distal bulge.

Ovigeral spine formula :- $\frac{12\text{-}16}{7} : \frac{9\text{-}12}{8} : \frac{7\text{-}10}{9} : \frac{9\text{-}12}{10}$ +S.

Chelicerae. Scape essentially cylindrical, uniformly setose (maximum seta length ca 1.5 - 2.0 x maximum scape diameter), subequal in length to chela. Palm constricted at base, widening distally, heavily setose, length ca 0.8 x subequal fingers. Movable finger non-setose. Base of movable finger with tuft of strong setae. Fingers with oxeote ends. Dentition uniform on both fingers, needle shaped, distally separated by ca 1.5 x basal width. Immovable 18-24. Movable 24-29.

Legs. Generally heavily setose. Relative coxal lengths :- 1 ≏ 3 = 0.66 x 2. Coxae sparsely setose with comb of dorsodistal setae over articular membranes. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur, heavily microsetose, subequal in length to tibia 1. In female, femur inflated with maximum diameter ca 0.2 x femur length. In male, femur of uniform diameter bearing 8 - 12 raised ventral cement tubercles. Tibia 1 length ca 0.8 x length tibia 2. Tibiae heavily setoes (maximum seta length ca 2.0 x maximum segment diameter). Tarsus length ca 0.25 x propodus length. Propodus armed with 9 - 12 ventral spines. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.33 x terminal claw length.

Size ranges. (Tables 2.4 & 2.5)

Distribution.

Eastern Arctic. (Map 2.3). The most abundant pycnogonid within the area. Common everywhere above 600 metres, except in the northeast Barents Sea, although it has also been recorded at more than 1400 metres in the Faroe Channel.

General. A high Arctic cold water species but not circumpolar, a gap existing in the distribution between the New Siberian Islands (140°E) and 120°W in the American Arctic. In the Atlantic, the most southerly record is from the Shetland Islands on the eastern side and Nova Scotia in the west.

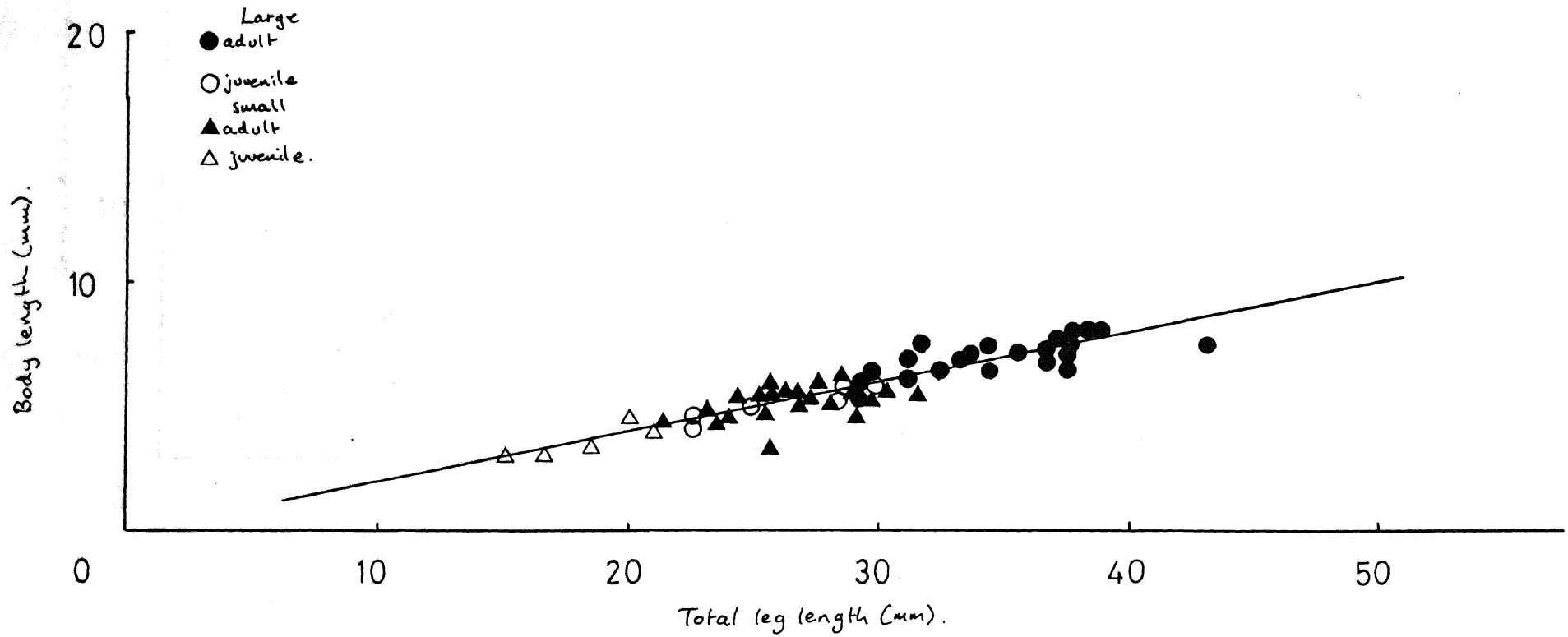
Remarks. The taxonomic status of this species has been subject to much controversy. Many authors having synonymized it with N.tenellum to form a composite species N.spinosum Goodsir (See N.tenellum, remarks).

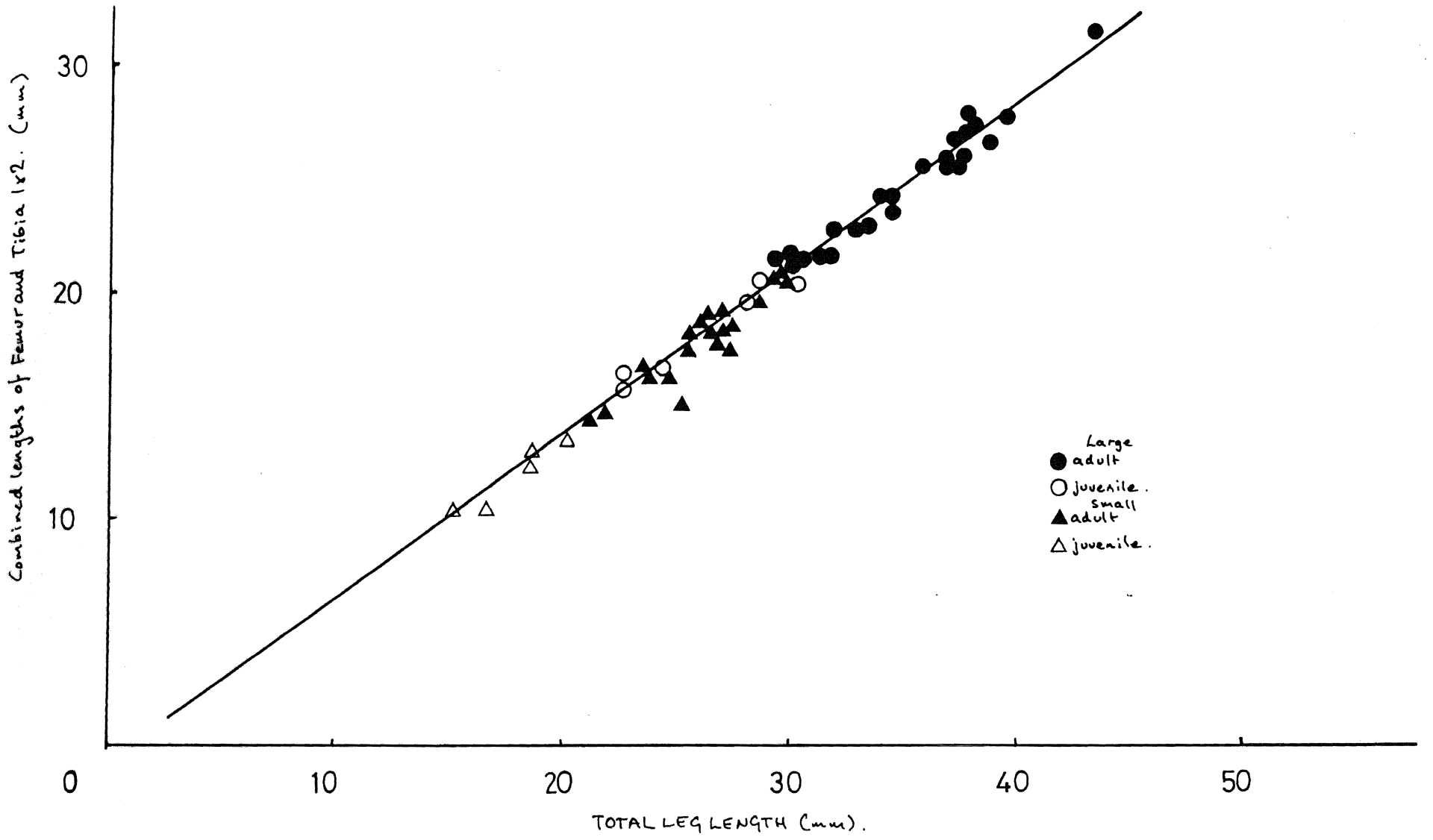
From the specimens examined this species shows a definite variation in adult size. Three samples were taken off West Spitsbergen and one from western Greenland. Of these all adult specimens were significantly smaller than those recorded from other areas.

Graphs 2.3 and 2.4 indicate that the only distinction which can be made between the two morphs is one of overall size. There is no discernible difference in their morphology and ,therefore, there is no argument for separating them into different species. It is interesting to note that there is no overlap between the two morphs for juvenile sizes and that for the adult sizes is slight.

The fact that the two morphs are indistinguishable morphologically, save in respect of size, indicates that the difference is probably due to external conditions, which affect the growth rates, rather than to a genetic difference.

GRAPH 2,3. NYMPHON HIRTIPES. Total leg length / Body length.





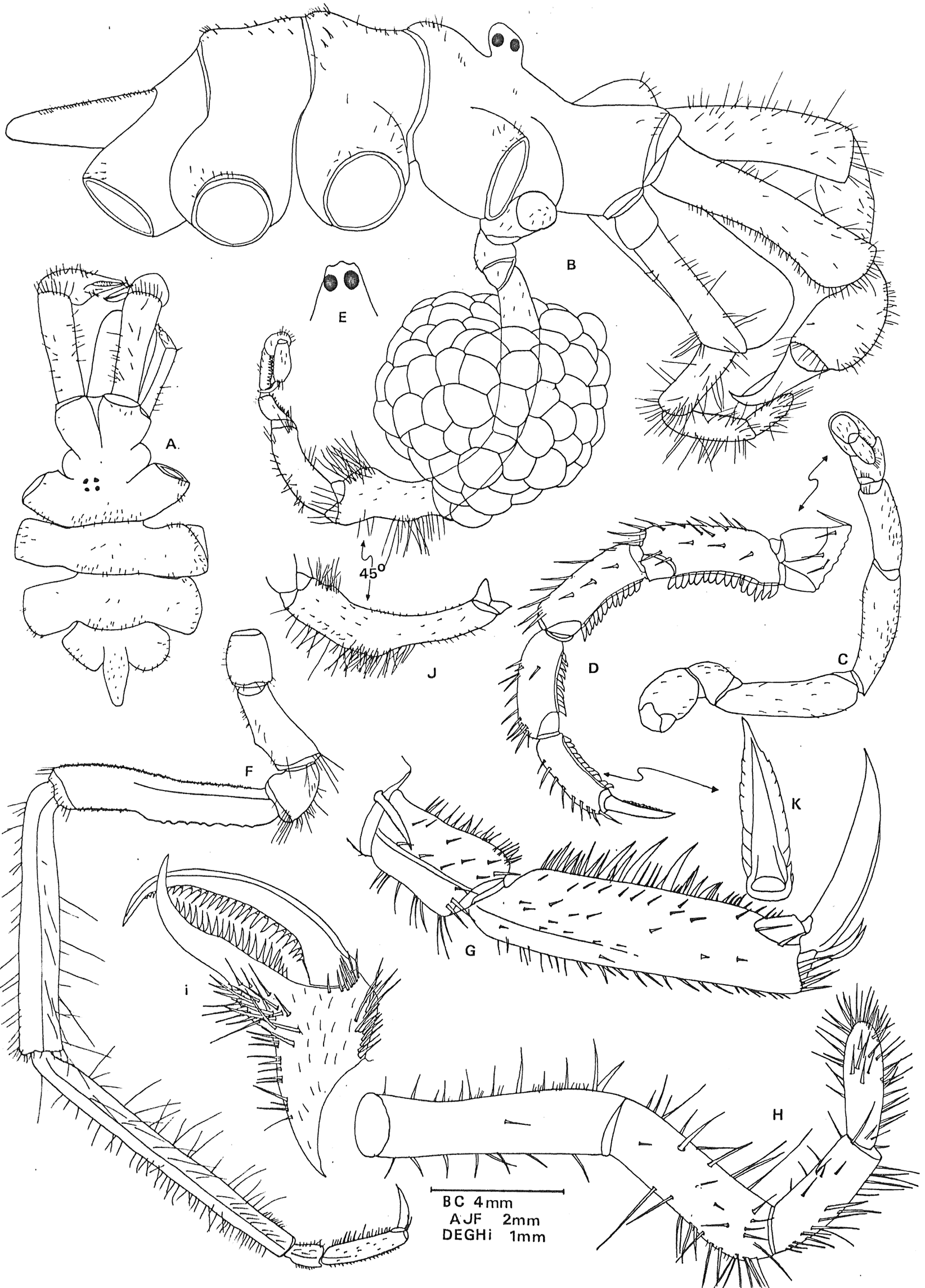
GRAPH 2;4 NYMPHON HIRTIPES Total leg length/ length of Femur and Tibiae.

Table 2.4 Nymphon hirtipes (Large morph). (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	5.92 - 8.16	5.28 - 7.84	3.20 - 6.08
Proboscis	3.20 - 4.00	2.88 - 3.84	1.60 - 3.04
Abdomen	1.92 - 2.08	1.60 - 1.76	1.12 - 1.56
Total palp	4.24 - 5.76	3.68 - 6.00	1.92 - 4.64
Cephalic somite length	3.88 - 4.00	2.40 - 3.84	1.96 - 3.36
Cephalic somite width	3.09 - 4.23	3.20 - 4.16	1.60 - 3.68
Oviger.4	2.20 - 2.72	1.79 - 2.20	
Oviger.5	2.24 - 3.62	1.82 - 1.90	
Oviger.6	1.18 - 1.90	0.99 - 1.30	
Coxa.1	1.12 - 1.92	0.96 - 1.76	0.80 - 1.44
Coxa.2	2.64 - 3.28	2.08 - 2.80	1.12 - 2.28
Coxa.3	1.12 - 1.76	1.04 - 1.76	0.64 - 1.28
Femur	6.08 - 7.68	6.00 - 9.44	3.28 - 6.08
Tibia.1	6.80 - 8.64	6.56 - 9.60	3.44 - 6.56
Tibia.2	8.32 - 10.56	8.16 - 12.16	4.80 - 8.08
Tarsus	0.88 - 1.12	0.64 - 1.28	0.48 - 0.80
Propodus	1.92 - 2.56	1.76 - 3.04	1.44 - 2.08
Terminal claw	1.28 - 1.64	1.02 - 2.28	0.80 - 1.12
Auxiliary claw	0.32 - 0.40	0.24 - 0.40	0.16 - 0.32

Table 2.5 Nymphon hirtipes (Small morph). (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	4.00 - 5.76	4.48 - 5.44	3.04 - 4.00
Proboscis	2.40 - 2.72	2.50 - 2.56	1.60 - 2.24
Abdomen	1.60 - 1.76	1.44 - 1.92	0.96 - 1.60
Total palp	3.20 - 4.48	3.28 - 4.48	1.92 - 2.96
Cephalic somite length	2.40 - 3.88	2.24 - 2.56	1.76 - 2.24
Cephalic somite width	2.40 - 3.04	2.40 - 2.72	1.92 - 2.72
Oviger.4	1.33 - 2.10	1.44 - 1.82	
Oviger.5	1.75 - 3.12	1.44 - 1.89	
Oviger.6	0.91 - 1.44	0.84 - 1.03	
Coxa.1	1.12 - 1.28	0.96 - 1.12	0.64 - 0.96
Coxa.2	1.60 - 2.24	1.60 - 1.92	1.20 - 1.60
Coxa.3	0.80 - 1.12	1.04 - 1.12	0.64 - 0.80
Femur	3.36 - 5.44	4.80 - 6.40	3.40 - 4.48
Tibia.1	4.96 - 6.08	5.12 - 6.40	3.28 - 4.96
Tibia.2	6.08 - 7.20	6.24 - 7.52	4.16 - 5.12
Tarsus	0.48 - 0.72	0.48 - 0.96	0.32 - 0.48
Propodus	1.76 - 2.08	1.92 - 2.08	1.12 - 1.92
Terminal claw	0.80 - 1.04	0.96 - 1.20	0.64 - 0.80
Auxiliary claw	0.16 - 0.32	0.24 - 0.40	0.08 - 0.24


A
B
C
D
E
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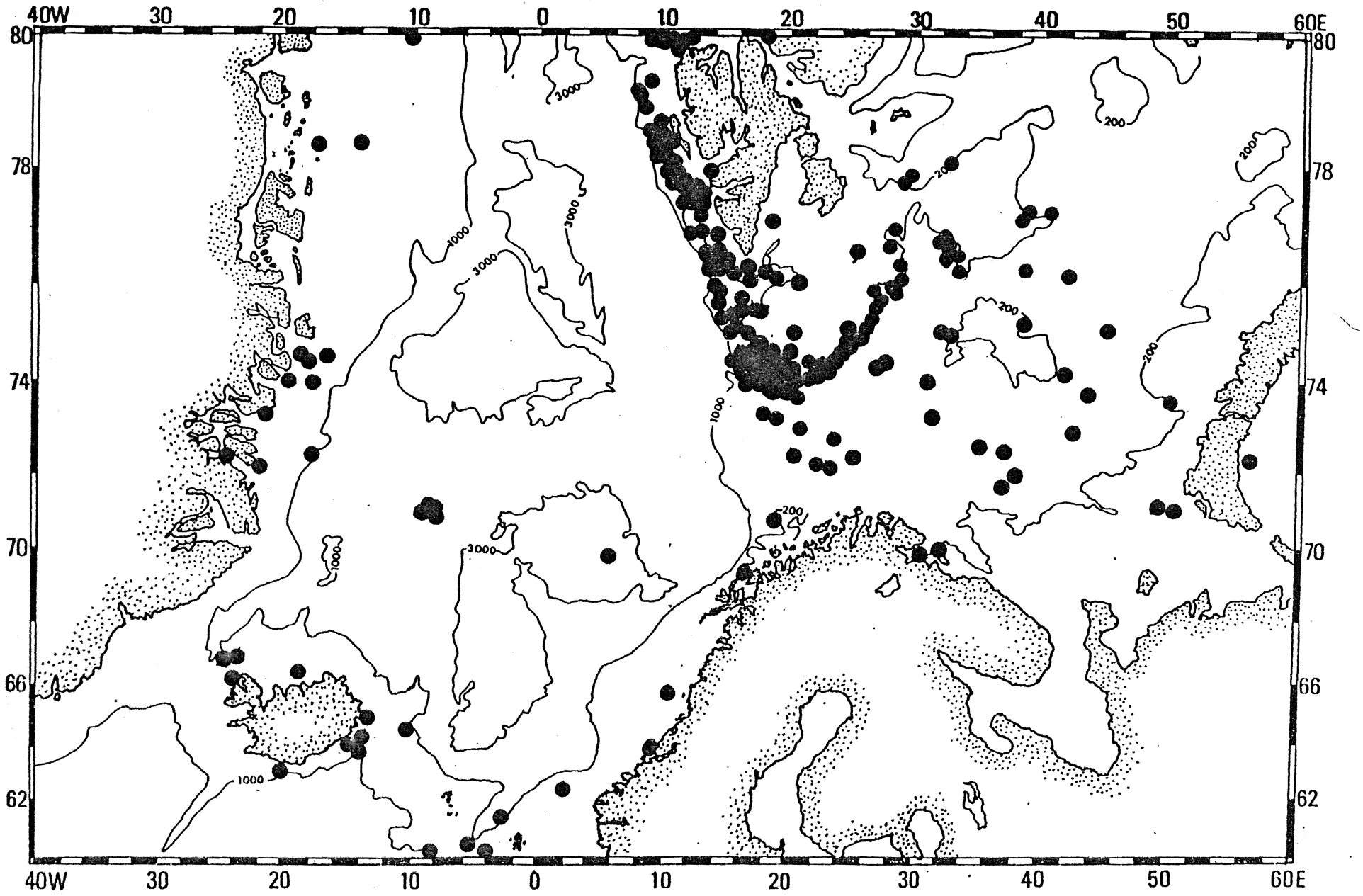
H
i
J
K
45°
BC 4mm
AJF 2mm
DEGHi 1mm

Map 2.3. Nymphon hirtipes.



Nymphon hirtum Fabricius, 1794.

Nymphon hirtum Fabricius, 1794: 417; Krøyer, 1844: 113; Krøyer (Gaimard), 1849: Pl 36, Figs 3a-g; Hodge, 1864: 116; Bucholtz, 1874: 397; Hansen, 1887: 161; Hedgpth, 1963: 1327.

Chaetonymphon hirtum; Sars, 1888: 352; 1891: 101, Pl 11, Figs 1a-g; Möbius, 1901: 48; Norman, 1908: 218; Stephensen, 1916: 401; Giltay, 1928: 209; Schimkewitsch, 1930: 327, Figs 77-80; Derjugin, 1935: 19; Losina-Losinsky, 1935: 19; Stephensen, 1936: 7; 1937: 2; 1943: 16.

Nymphon pallenoides Sars, 1879: 470, (partim).

Nymphon spinosum Goodsir, 1842: 139, Pl 3, Fig 3; Appellöf, 1916: 6, (partim).

Nymphon femoratum Leach, 1814: 45, Pl 19, Fig 2; Johnston, 1837: 380.

Material examined. (See Appendix I).

Description (fig 2.11).

Trunk. Three complete intersegmental articulations, setose dorsally. Lateral processes constricted at base, separated by ca 0.25 x their proximal diameter, lacking tubercles or setae. Neck indistinct. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with domed crown, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process and posterior margin of cephalic lobe. Abdomen pyriform. Posture, ca 30-40° from horizontal.

Proboscis. Length ca 0.7 - 0.8 x length of cephalic somite. TYPE J'.

Palps. 1st - 4th essentially cylindrical, 5th ovate. Relative segment lengths :- $1 < 4 \triangleq 5 = 0.33 \times 2 \triangleq 3$. Setation, 1st absent, 2nd and 3rd sparse, 4th and 5th heavy microsetose.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 < 5$.

In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.33 - 0.4 x length segment 5.

Ovigeral spine formula :- $\frac{12-13}{7} : \frac{8-9}{8} : \frac{7-8}{9} : \frac{8-9}{10}$ +S.

Chelicerae. Scape essentially cylindrical, sparsely setose dorsally, length ca 1.25 x chela length. Palm essentially cylindrical, sparsely microsetose, length ca 1.2 x movable finger length. Fingers with oxeote ends, set at 90° to palm. Immovable finger length ca 0.75 x length of movable finger. Dentition uniform on both fingers, tightly packed on immovable finger and separated by ca 0.5 -1.0 x their basal width on movable finger. Both fingers with 14 - 16 teeth.

Legs. Entire leg heavily microsetose (Maximum seta length ca 0.33 x maximum segment diameter). Relative coxal lengths :- 1≏3 = 0.5 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length subequal to tibia 1 length, ca 0.8 x length of tibia 2. Tarsus length ca 0.5 x length of propodus. Propodus slightly curved, bearing 8 - 11 uniform ventral spines, centrally situated. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.5 -0.7 x terminal claw length.

Size ranges (table 2.6).

Distribution.

Eastern Arctic. (Map 2.4). Occurs from Iceland to the Murmansk Sea and also along the Norwegian coast. It has been been recorded above 71°North. A shallow water species, rarely found below 200 metres.

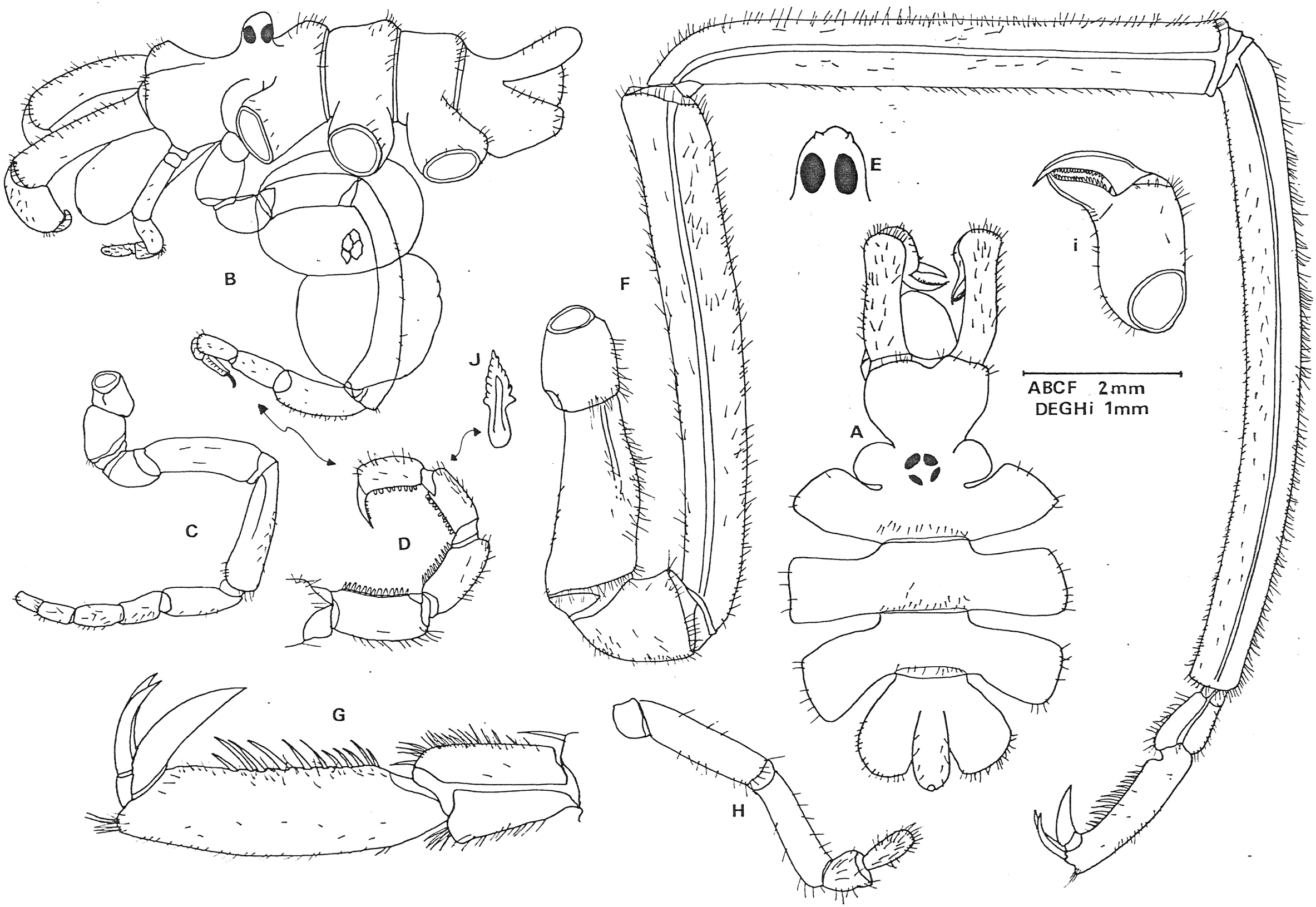
General. Hedgpeth (1963) has recorded this species near Koh Island (69.44N 77.38W), this being the only record west of Iceland. It is not generally considered to be an Arctic species, being found as far south as Belgium. Norman (1908) gives several locations for it around the coast of Britian.

Remarks. Nymphon femoratum Leach (1814), N.spinosum Goodsir (1842) and N.pallenoides Sars (1879) are all synonyms of this species. Its distribution separates it from it close relatives, N.hirtipes and N.tenellum, which also differ morphologically from N.hirtum in leg setation and chela size (See N.tenellum, 'Remarks).

Table 2.6 Nymphon hirtum size ranges. (In millimetres).

	MALE	FEMALE
Trunk	4.40 - 4.64	4.40
Proboscis	1.84 - 1.92	1.72
Abdomen	0.72 - 0.96	0.72
Total palp	2.08 - 2.48	2.36
Cephalic somite length	2.24 - 2.40	2.36
Cephalic somite width	2.56 - 2.72	2.48
Oviger.4	1.28 - 1.44	1.04
Oviger.5	2.32 - 2.72	1.20
Oviger.6	0.80 - 0.96	0.64
Coxa.1	1.04 - 1.12	0.96
Coxa.2	2.08 - 2.48	1.66
Coxa.3	0.80 - 0.88	0.80
Femur	5.36 - 6.00	5.80
Tibia.1	5.60 - 6.24	5.82
Tibia.2	6.80 - 7.36	6.62
Tarsus	0.72 - 0.80	0.64
Propodus	1.68 - 1.84	1.70
Terminal claw	0.56 - 0.72	0.64
Auxiliary claw	0.48 - 0.52	0.42

N.B. No juvenile specimens sampled, one female specimen sampled.


B
F
J
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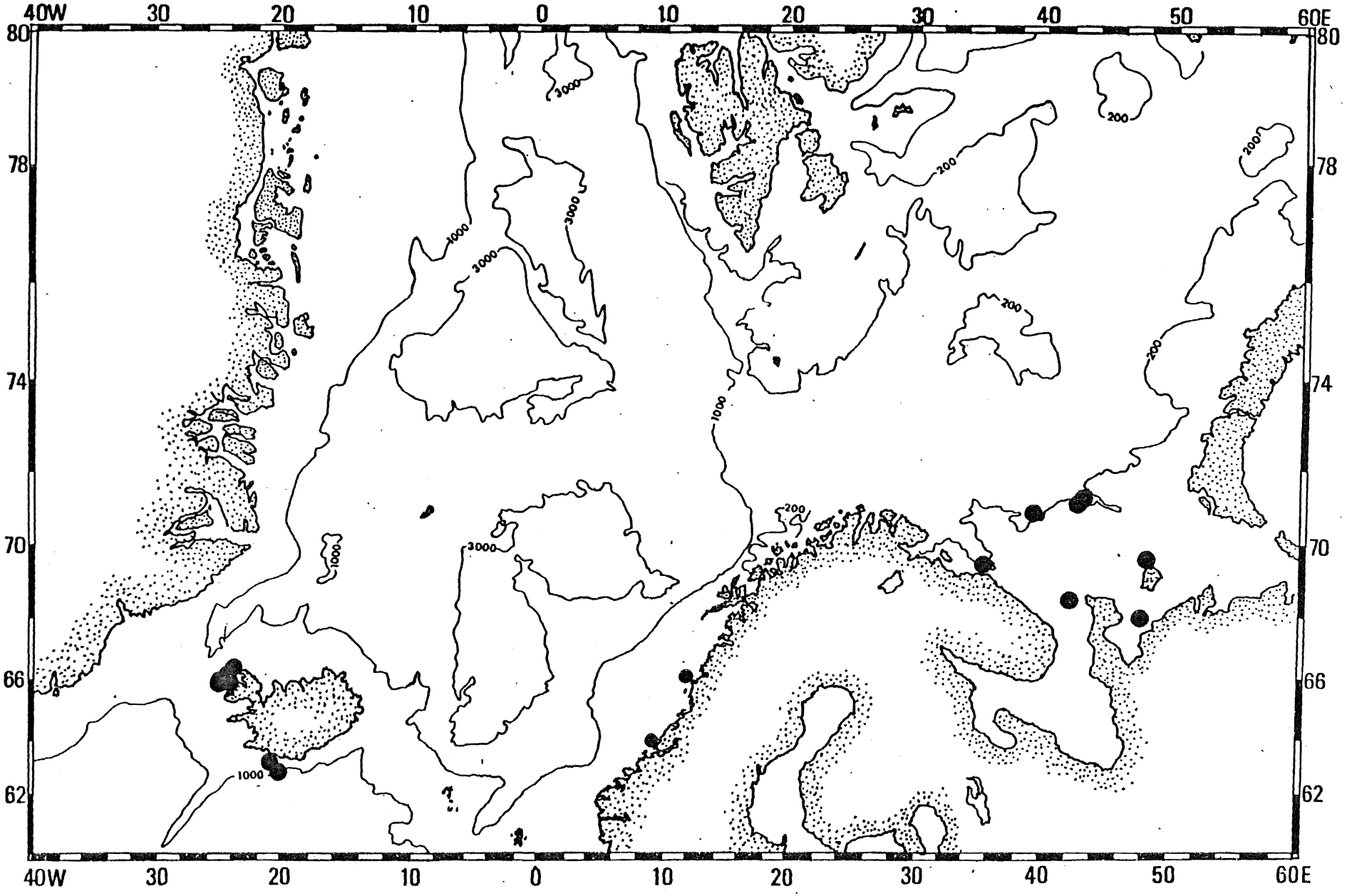
D
E
i
A
G
H
ABCF 2mm
DEGHi 1mm

Map 2.4. Nymphon hirtum.



Nymphon leptocheles Sars, 1888.

Nymphon leptocheles Sars, 1888: 348; 1891: Pl 8, Figs 1a-i; Meinert, 1899: 43; Möbius, 1901: 43; Norman, 1908: 213; Stephensen, 1913: 394; Schimkewitsch, 1930: 445, Figs 122-127; Stephensen, 1933: 15; 1936: 14; 1937: 4; Hedgpeth, 1963: 1322.

Nymphon groenlandicum Meinert, 1899: 41, Pl 3, Figs 14-22; Norman, 1908: 213; Stephensen, 1913: 395; 1933:15.

Material examined. (See Appendix I).

Description (fig 2.12).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by 2.0 - 3.0 x their proximal diameter, lacking tubercles or setae. Neck constricted anteriorly, length ca 2.0 x basal diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with 2 dorsolateral processes, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture 45° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 5 < 4 < 2 \triangleq 3$. Setation, 1st absent, 2nd very sparse, 3rd and 4th sparse, 5th heavy, especially distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$. In female, lengths of segments 5 and 6 are subequal. In male, segment 6 length ca 0.3 x length segment 5. Segment 5 in male possesses 5 - 7 ventral serrations.

Ovigeral spine formula :- $\frac{16\text{-}18}{7} : \frac{14\text{-}15}{8} : \frac{12\text{-}13}{9} : \frac{14\text{-}15}{10} + S.$

Chelicerae. Scape essentially cylindrical, length ca 1.4 - 1.6 x chela length. Palm essentially cylindrical, sparsely setose, length ca 0.8 x length of subequal fingers (movable finger very

slightly longer). Base of immovable finger with tuft of setae. Movable finger non-setose. Fingers with oxeote ends. Dentition uniform on both fingers, separated distally by ca 1.0 - 1.5 x basal width. Movable finger dentition length ca 0.66 x immovable teeth length. Immovable 28-32. Movable 22-26.

Legs. Sparsely microsetose. Relative coxal lengths :- 1 ≏ 3 = 0.25 - 0.3 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length < tibia 1 length < tibia 2 length (femur length ca 0.75 x length tibia 2). Tarsus length ca 1.6 x propodus length. Propodus armed with 20 - 30 uniform ventral spines. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.25 x length of terminal claw.

Size ranges. (See table 2.7).

Distribution.

Eastern Arctic. (Map 2.5). Not a common oceanic species, it appears to inhabit deep water fjords. The species, according to Sars (1891), is pretty frequent along the whole of the Norwegian coast as far north as the Lofoten Islands. Subsequent records (Meinert, 1899; Norman, 1908; Schimkewitsch, 1930) show it to occur off the coast of northern Norway, West Spitsbergen, Bear Island and western Iceland. Not generally found above 100 metres, with a mean depth of 300 metres.

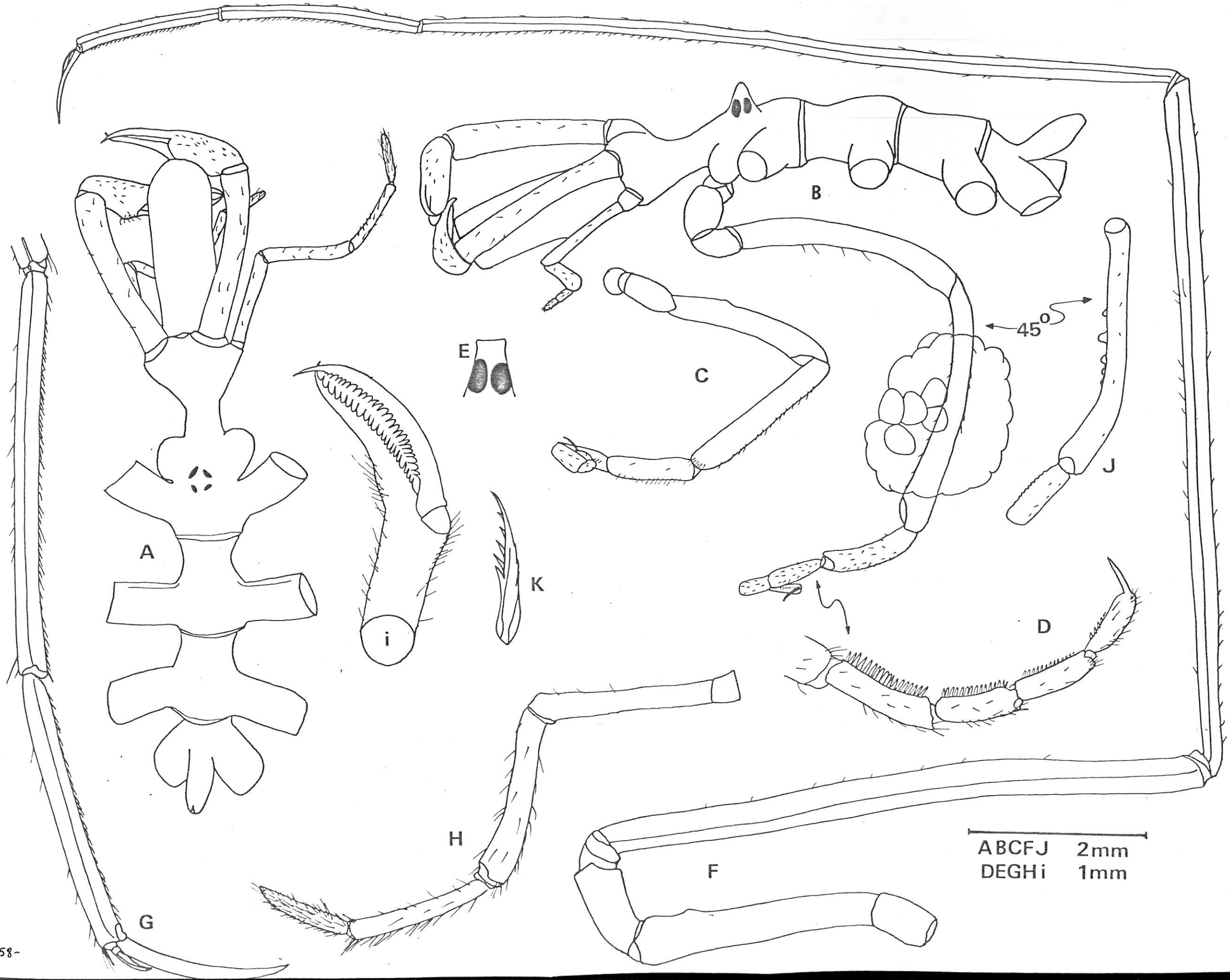
General. Infrequent outside the Eastern Arctic. Records show its distribution to extend to western Greenland (Meinert, 1899) and the west coast of Ireland (Carpenter, 1898; Meinert, 1899) at depths of between 100 and 1100 metres.

Remarks. This species includes Nymphon groenlandicum Meinert (1899) which Norman (1908) describes as "scarcely indistinguishible from N. leptocheles ". The only difference appears to be that

N. groenlandicum has more heavily setose walking legs, the tibiae especially. Museum material for this species is scarce. During the course of this research only 2 specimens, an adult female and an adult male bearing ovigeral egg masses, have been examined.

Table 2.7 Nymphon leptocheles size ranges. (In millimetres).

	MALE	FEMALE
Trunk	2.96	3.70
Proboscis	1.84	2.30
Abdomen	0.64	0.80
Total palp	3.66	4.12
Cephalic somite length	2.00	2.50
Cephalic somite width	1.76	2.20
Oviger.4	2.64	1.80
Oviger.5	2.80	1.86
Oviger.6	0.56	0.90
Coxa.1	0.64	0.80
Coxa.2	2.64	3.30
Coxa.3	0.88	1.10
Femur	6.00	7.50
Tibia.1	7.60	9.50
Tibia.2	8.88	11.10
Tarsus	2.32	2.90
Propodus	1.52	1.90
Terminal claw	0.96	1.20
Auxiliary claw	0.24	0.30


A
B
C
D
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i
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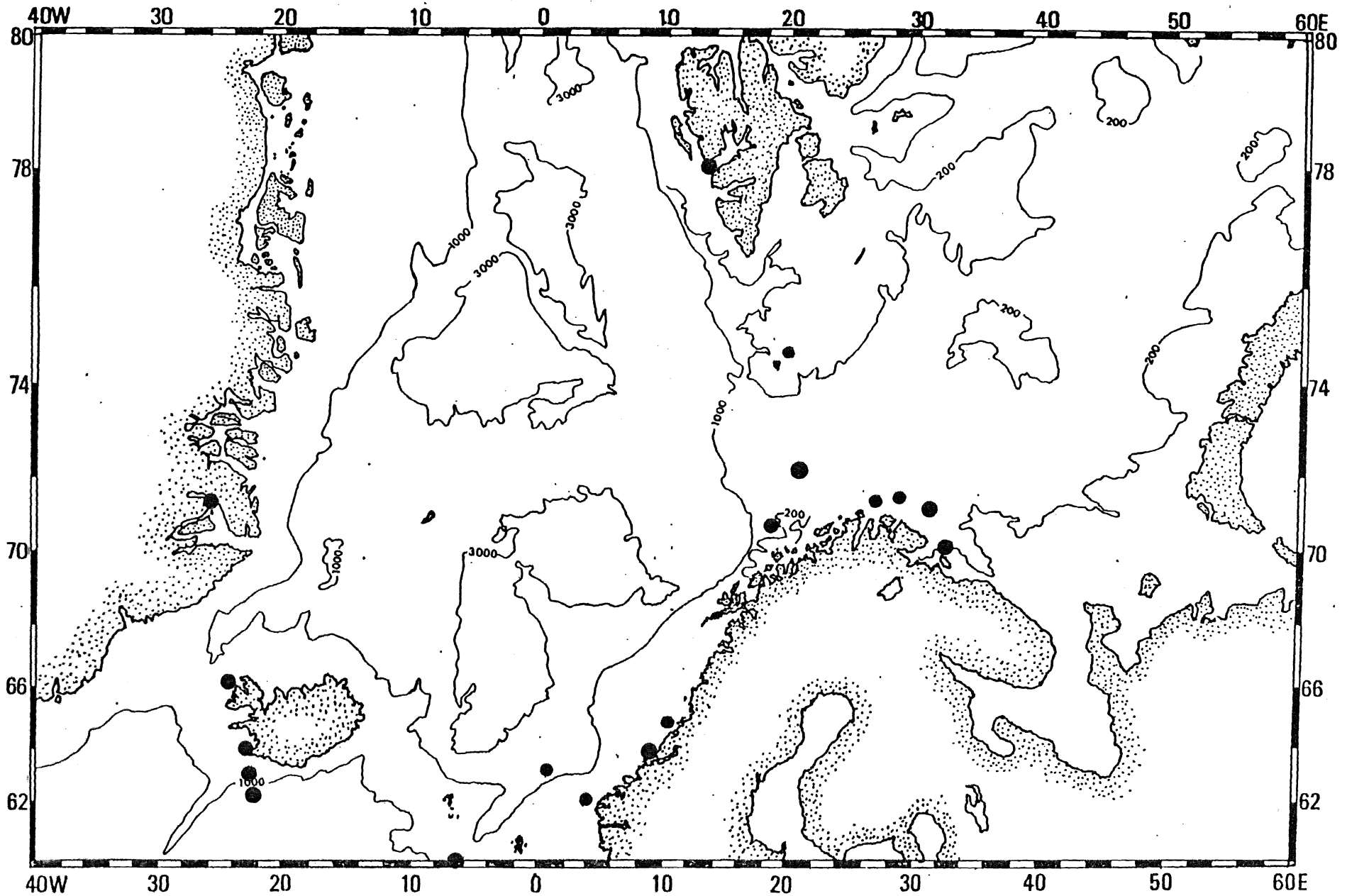
45°
ABCFJ 2mm
DEGHi 1mm

Map 2.5. Nymphon leptocheles.



Nymphon longimanum Sars, 1888.

Nymphon longimanum Sars, 1888: 351; 1891: 93, Pl 10, Figs 1a-f; Lonneberg, 1902: 356; Norman, 1908: 217; Stephensen, 1912: 588; 1913: 388; Schimkewitsch, 1930: 489; Stephensen, 1936: 22; 1943: 25; Hedgpeth, 1963: 1322.

Material examined. (See Appendix I).

Description. (fig 2.13).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 0.33 - 0.66 x their proximal diameter, lacking tubercles or setae. Neck narrow, length ca 0.5 x 0.75 x diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with domed crown, bearing 4 pigmented eyes. Ovigeral mound touching anterior margin of 1st lateral process. Abdomen pyriform. Posture ca 40° from horizontal.

Proboscis. Length ca 0.8 x length of cephalic somite. TYPE B'".

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 4 < 5 < 2 \doteq 3$. Setation, 1st absent, 2nd and 3rd sparse, 4th heavy ventrally, 5th heavy ventrally and distally.

Adult oviger. Relative segment lengths :- $1 \doteq 2 \doteq 3 \doteq 7 \doteq 8 \doteq 9 \doteq 10 < 6 < 4 \doteq 5$.

Ovigeral spine formula :- $\frac{16\text{-}19}{7} : \frac{14\text{-}17}{8} : \frac{13\text{-}16}{9} : \frac{14\text{-}17}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose, length ca 1.33 x length of chela. Palm essentially cylindrical, sparsely setose, length subequal with fingers. Fingers subequal. Base of immovable finger with tuft of setae. Movable finger non-setose. Fingers with oxeote ends. Dentition uniform on both fingers, needle shaped, unevenly spaced. Immovable 21 - 23. Movable 25 - 27.

Legs. Generally sparsely microsetose. Relative coxal lengths :- 1≏3 = 0.33 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length < tibia 1 length < tibia 2 length (femur length ca 0.5 - 0.6 x length tibia 2). Tarsus length ca 1.2 x propodus length. Propodus armed with 30 - 40 uniform venral spines. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.1 x terminal claw length.

Size ranges. (See table 2.8).

Distribution.

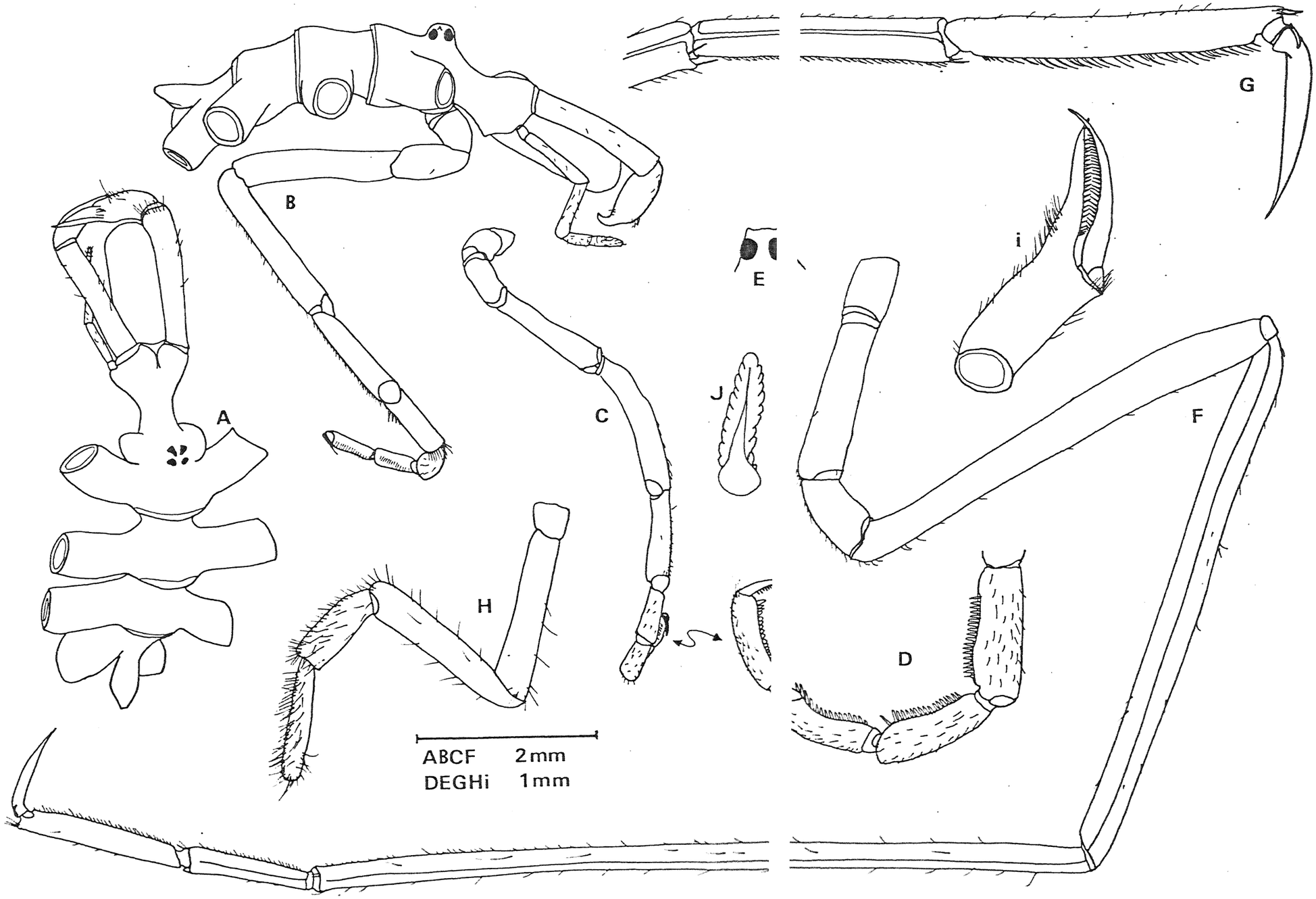
Eastern Arctic. (Map 2.6). Rare within the area. Three records have been reported from Jan Mayan, Franz Joseph Land and West Spitsbergen. Lonneberg (1902) has also recorded it from eastern Greenland. Appears to be a shallow water species in that it is not found below 150 metres and has a mean depth range of 20 - 50 metres.

General. Although few records exist, Schimkewitsch (1930) reports the species to be widespread, especially within the Kara Sea.

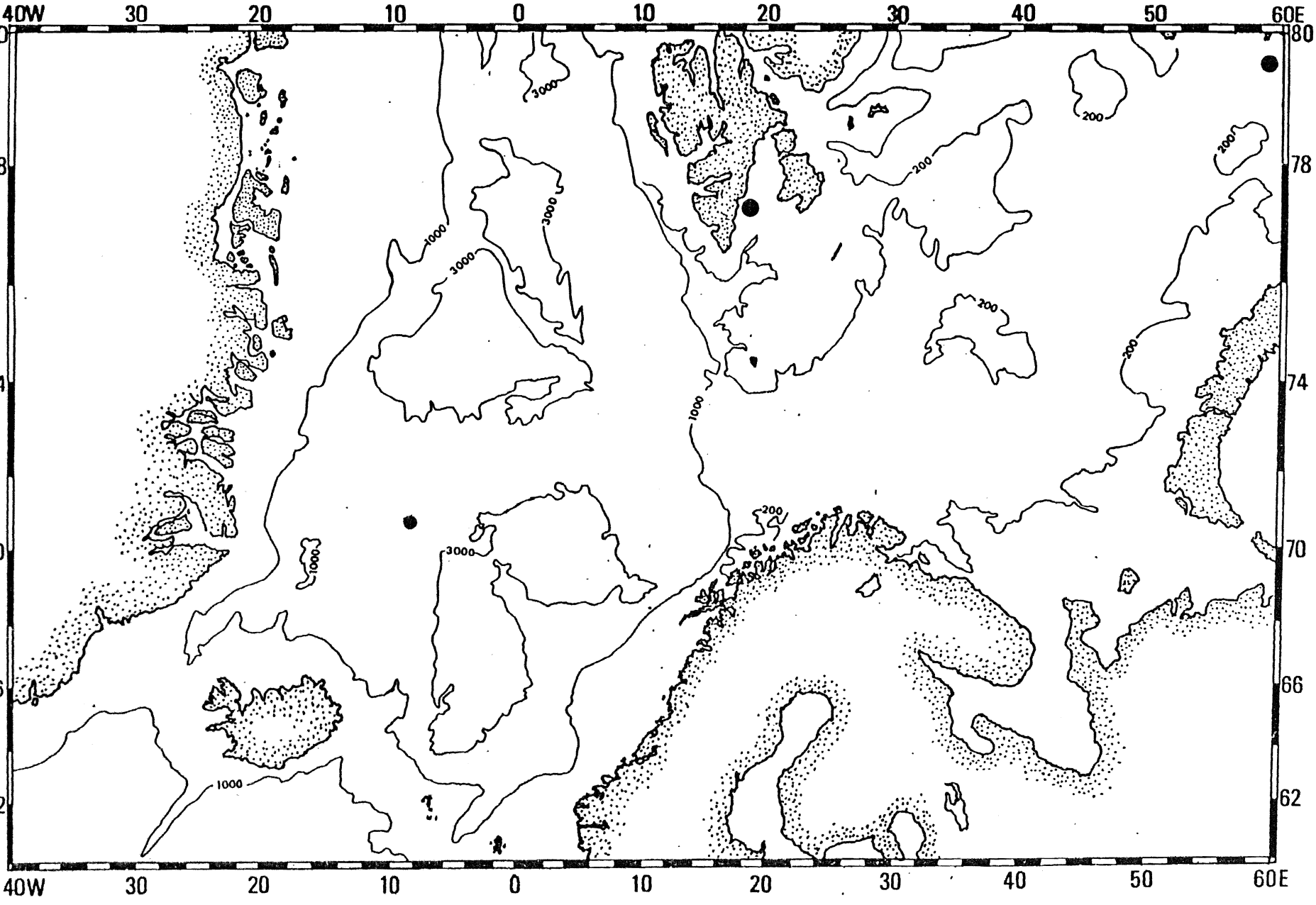
Remarks. Stephensen (1936) described this species as a high arctic form. From occurrences within the Eastern Arctic I would agree with this conclusion, the species being located only in areas where cold currents predominate.

Table 2.8. *Nymphon longimanum* size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	3.52	3.62 - 4.48	2.08 - 3.20
Proboscis	1.60	1.82 - 2.08	1.12 - 1.60
Abdomen	0.48	0.42 - 0.48	0.24 - 0.32
Total palp	2.40	2.30 - 3.20	1.52 - 2.16
Cephalic somite length	1.76	1.86 - 2.08	1.20 - 1.60
Cephalic somite width	2.00	2.12 - 2.24	1.44 - 1.60
Oviger.4	1.63	1.90	
Oviger.5	1.75	1.90	
Oviger.6	1.06	1.25	
Coxa.1	0.80	0.72 - 0.96	0.48 - 0.52
Coxa.2	2.24	1.96 - 2.24	0.96 - 1.76
Coxa.3	0.96	0.96 - 1.28	0.48 - 0.64
Femur	5.12	4.48 - 6.56	2.08 - 3.68
Tibia.1	6.40	5.42 - 7.36	2.88 - 4.56
Tibia.2	8.80	7.86 - 12.64	4.08 - 8.32
Tarsus	1.44	1.24 - 1.92	0.64 - 1.20
Propodus	1.60	1.48 - 2.24	1.20 - 1.60
Terminal claw	0.96	0.96 - 1.12	0.56 - 0.80
Auxiliary claw	0.005	0.005	0.0035


A
B
C
D
E
F
G
H
i
J
ABCF 2mm
DEGHi 1mm

Map 2.6. Nymphon longimanum.



distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 \triangleq 4 \triangleq 5$. In female, segment 6 length ca 0.75 x length segment 5. In male, segment 6 length ca 0.5 - o.66 x length segment 5. In male, 5th segment distally bulbous.

Ovigeral spine formula :- $\frac{15\text{-}16}{7} : \frac{11\text{-}12}{8} : \frac{10\text{-}11}{9} : \frac{12\text{-}14}{10} + S.$

Chelicerae. Scape essentially cylindrical, curved, subequal in length to chela. Palm essentially cylindrical, sparsely setose, length ca 1.2 x length of subequal fingers. Fingers with oxeote ends. Immovable finger gently sigmoid with tuft of sparse setae over base. Movable finger arcuate, non-setose. Dentition uniform on both fingers, needle shaped, separated distally by ca 0.5 - 1.0 x basal width. Immovable 20 - 22. Movable 22 - 24.

Legs. Generally sparsely setose. Relative coxal lengths :- $1 \triangleq 3 = 0.33$ x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur andtibia 1 subequal in length, ca 0.66 - 0.75 x length of tibia 2. Tarsus length ca 0.33 x length of tibia 2. Propodus length ca 0.66 x tarsus length. Propodus armed with 20 -25 ventral spines. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.25 - 0.33 x terminal claw length.

Size ranges. (See table 2.9).

Distribution.

Eastern Arctic. (Map2.7). Widespread along the Norwegian coast (Sars,1891), White Sea (Schimkewitsch, 1930) and Franz Joseph Land (Carpenter, 1898). Also recorded from Bear Island and West Spitsbergen (Appellöf, 1916) although not from Iceland and eastern Greenland. Appears to be a shallow water species, rarely found below 200 metres.

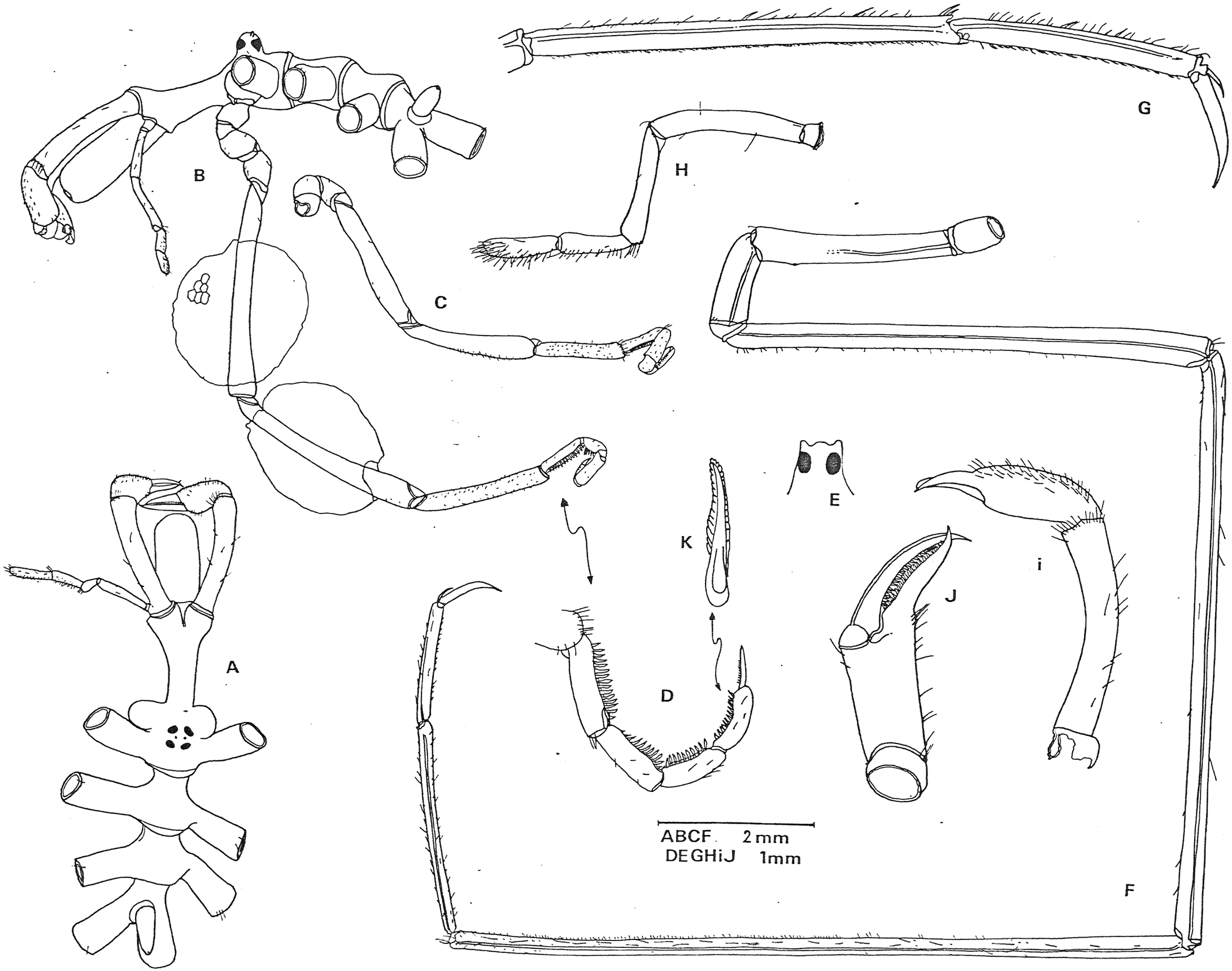
General. This is a circumpolar species occurring in the Bering Sea,

Sea of Okhotsk and the Sea of Japan (Hedgpeth, 1963). Its southern limit in the Atlantic is Cape Cod in the west and the Durham coast in the North Sea (Hodge, 1867). A shallow water species, usually not found at depths greater than 150 metres, although it has been recorded down to 900 metres off Cape Cod.

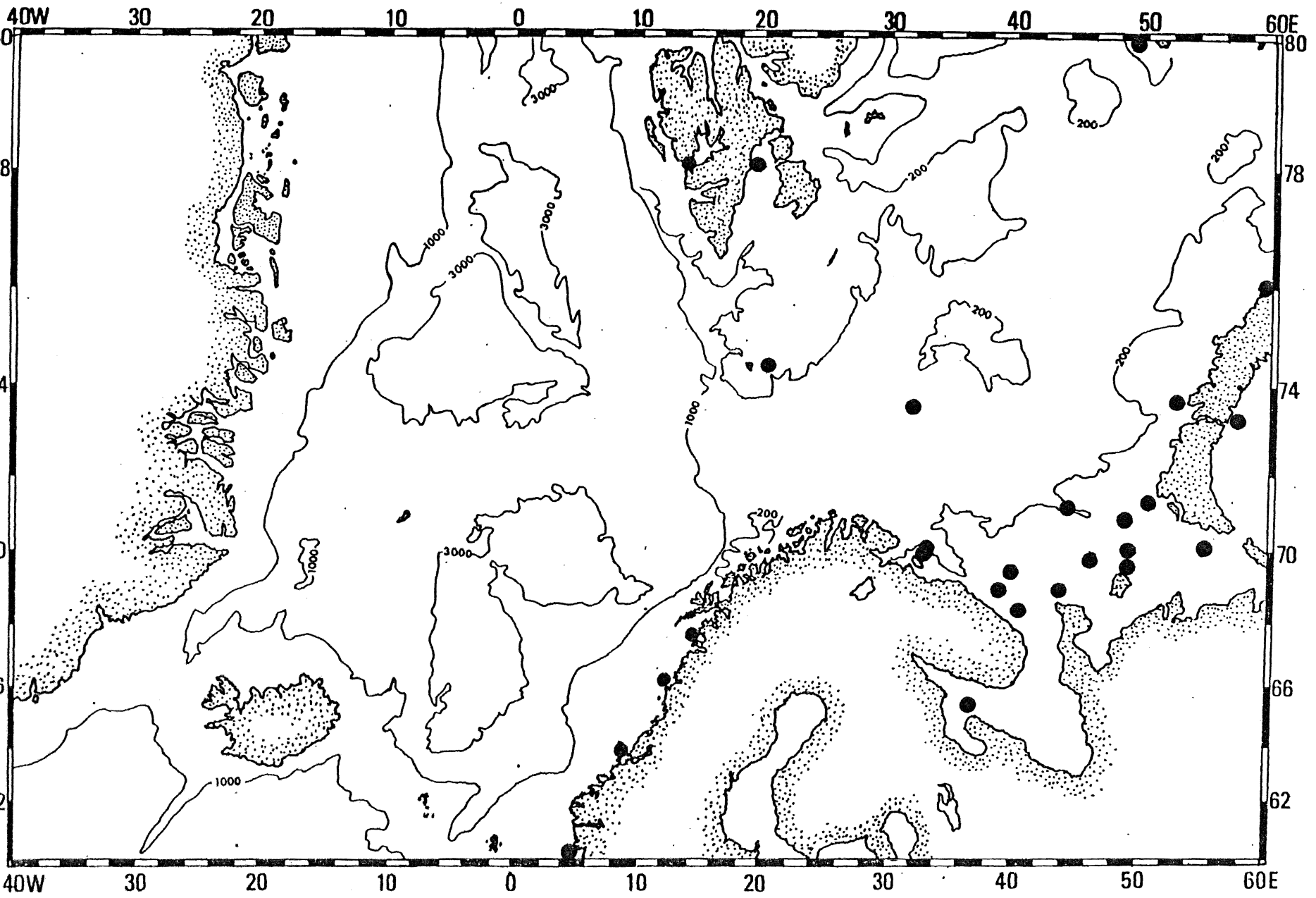
Remarks. There are two major varieties occurring within this species, Nymphon longitarse var minus, Schimkewitsch (1930) has a shorter tarsal segment than the usual form and N.longitarse var brevicollis, Losina-Losinsky (1935) has a shorter neck and closer lateral processes. Hedgpeth (1963) considers that the records of the latter variation add little to what is already known of the distribution. The specimens of N.longitarse recorded by Hansen (1887) were later removed to form a separate species, N.microrhynchum Sars (1891).

Table 2.9 Nymphon longitarse size ranges. (In millimetres).

	MALE	FEMALE
Trunk	3.68 - 4.48	3.60 - 3.92
Proboscis	1.28 - 1.60	1.36 - 1.42
Abdomen	0.40 - 0.64	0.40 - 0.56
Total palp	1.84 - 2.64	2.36 - 2.52
Cephalic somite length	1.52 - 2.48	1.84 - 2.16
Cephalic somite width	1.52 - 2.08	1.68 - 1.84
Oviger.4	1.25 - 2.77	1.56 - 1.82
Oviger.5	1.22 - 2.85	1.42 - 1.71
Oviger.6	0.80 - 1.63	0.95 - 1.10
Coxa.1	0.56 - 0.64	0.40 - 0.68
Coxa.2	1.76 - 2.96	1.44 - 1.92
Coxa.3	0.80 - 1.12	0.88 - 1.20
Femur	4.24 - 6.64	4.72 - 7.36
Tibia.1	4.96 - 7.68	5.60 - 7.84
Tibia.2	6.50 - 10.80	7.68 - 10.80
Tarsus	1.92 - 2.56	2.16 - 2.64
Propodus	1.20 - 1.36	1.20 - 1.36
Terminal claw	0.56 - 0.68	0.56 - 0.68
Auxiliary claw	0.20 - 0.24	0.16 - 0.24


B
C
H
G
A
K
E
D
J
i
F
ABCF 2mm
DEGHiJ 1mm

Map 2.7. Nymphon longitarse.



Nymphon macronyx Sars, 1877.

Nymphon macronyx Sars, 1877: Vol 2, 365; Hoek, 1881: 95, Pl 15, Figs 1-7; Hansen, 1887: 167, Pl 18, Figs 6a-c; Meinert, 1899: 43; Hedgpeth, 1963: 1332.

Chaetonymphon macronyx; Sars, 1888: 354, No 36; 1891: 111, Pl 12, Figs 2a-k; Carpenter, 1898: 632, Pl 46, Figs 14-16; Möbius, 1901: 49; Norman, 1908: 220; Stephensen, 1913: 403; Schimkewitsch, 1930: 365, Figs 88-92; Stephensen, 1933: 9; 1936: 8; 1943: 16, Fig 5.

Material examined. (See Appendix I).

Description. (fig 2.15).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 0.75 x their diameter, lacking tubercles, setose dorsally. Neck cylindrical, length subequal to diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, conical with 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture ca 80° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B'.

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 5 < 4 < 3 < 2$. Setation, 1st and 2nd absent, 3rd sparse distally, 4th heavy ventrally and distally, 5th heavy.

Adult oviger. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$. In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.4 x length segment 5. In male, 5th segment curved.

Ovigeral spine formula :- $\frac{13-14}{7} : \frac{11-12}{8} : \frac{10-11}{9} : \frac{11-12}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose, length ca 1.4 x chela length. Palm essentially cylindrical, very sparsely setose, length ca 0.66 x length of very slender subequal fingers. Base of immovable finger with tuft of heavy setae, movable finger non-setose. Fingers with oxeote ends. Dentition uniform on both fingers, needle shaped, separated distally by ca 1.0 - 1.5 x basal width. Both fingers with 11 - 13 teeth.

Legs. Generally sparsely setose. Relative coxal lengths ;- 1 ≏ 3 = 0.33 x 2. Coxae with dorsodistal comb of setae over articular membranes. Genital por ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length. In female, femur inflated proximally. In male, femur uniform in diameter, bearing 4 - 8 shallow ventral cement tubercles. Femur sparsely setose in both sexes. Tibia 1 length ca 0.8 x length tibia 2. Tibia 1 and 2 sparsely setose (Maximum seta length ca 1.5 - 2.0 x maximum segment diameter). Tarsus length ca 0.5 x propodus length. Tarsus and propodus armed with uniform ventral spines, propodus 27 - 30, tarsus 9 - 11. Terminal claw length ca 0.75 propodus length. Auxiliary claw length ca 0.1 - 0.2 x terminal claw length.

Size ranges (See table 2.10).

Distribution.

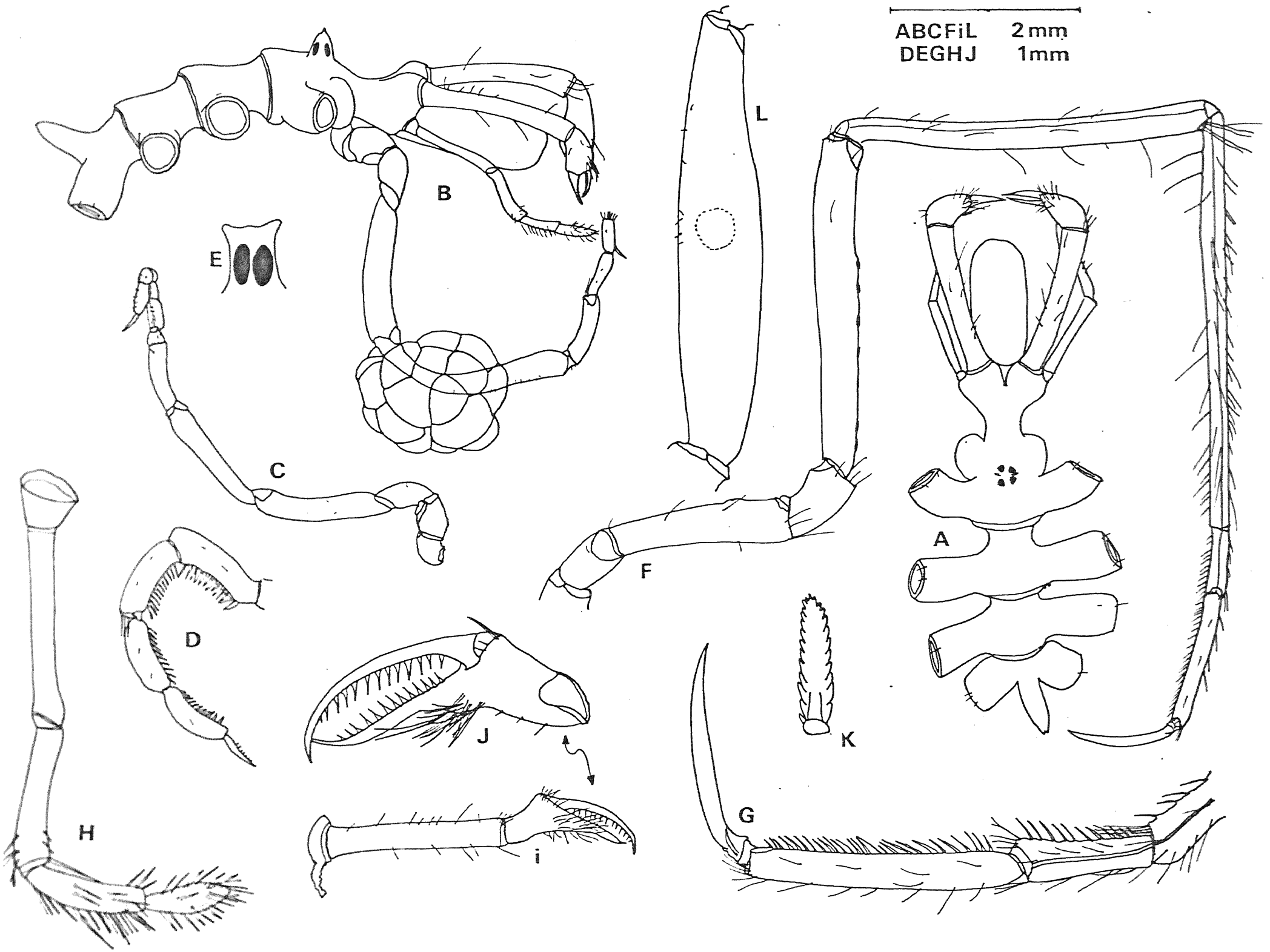
Eastern Arctic. (Map 2.8). Widespread and locally abundant. Most abundant in the Faroe Channel and southeast Barents Sea. Recorded also between the Faroes and Iceland, Franz Joseph Land, Kara Sea and off the Norwegian coast. Rarely found above 150 metres and common below 1000 metres in the Faroe Channel.

General. Further distributed to the west of Greenland and in the Kara Sea.

Remarks. Appears to be a cold water species. Depth varies depending on region. Found at a greater depth within the southern part of its distribution (1400 metres in the Faroe Channel compared with ca 200 metres near Hope Island). Many authors have included this species within the genus Chaetonymphon Sars (1888). Hedgpeth (1948) included Chateonymphon with Nymphon in agreement with Calman (1912) and Gordon (1932).

Table 2.10. Nymphon macronyx size ranges. (In millimetres).

Trunk	3.04 - 3.36	3.20 - 3.60	2.32 - 2.72
Proboscis	1.44 - 1.52	1.28 - 1.76	1.20 - 1.44
Abdomen	0.48 - 0.72	0.48 - 0.68	0.32 - 0.40
Total palp	1.68 - 2.24	2.04 - 2.72	1.56 - 1.92
Cephalic somite length	1.44 - 1.76	1.60 - 1.76	1.36 - 1.44
Cephalic somite width	1.44 - 1.68	1.44 - 1.76	1.28 - 1.44
Oviger.4	1.25 - 1.60	1.10 - 1.29	
Oviger.5	1.37 - 1.82	1.14 - 1.37	
Oviger.6	0.61 - 0.72	0.57 - 0.68	
Coxa.1	0.48 - 0.76	0.64 - 0.72	0.48 - 0.56
Coxa.2	1.72 - 1.76	1.20 - 1.52	1.12 - 1.28
Coxa.3	0.56 - 0.64	0.56 - 0.64	0.44 - 0.72
Femur	3.28 - 4.52	3.36 - 4.64	2.08 - 3.24
Tibia.1	3.36 - 3.76	3.60 - 4.56	3.20 - 3.44
Tibia.2	3.92 - 4.32	3.88 - 4.88	3.60 - 4.28
Tarsus	0.56 - 0.72	0.56 - 0.80	0.52 - 0.60
Propodus	1.36 - 1.44	1.44 - 1.64	1.20 - 1.36
Terminal claw	1.12 - 1.16	0.96 - 1.20	0.80 - 1.00
Auxiliary claw	0.08 - 0.12	0.08 - 0.12	0.04 - 0.08


ABCFiL 2mm
DEGHJ 1mm
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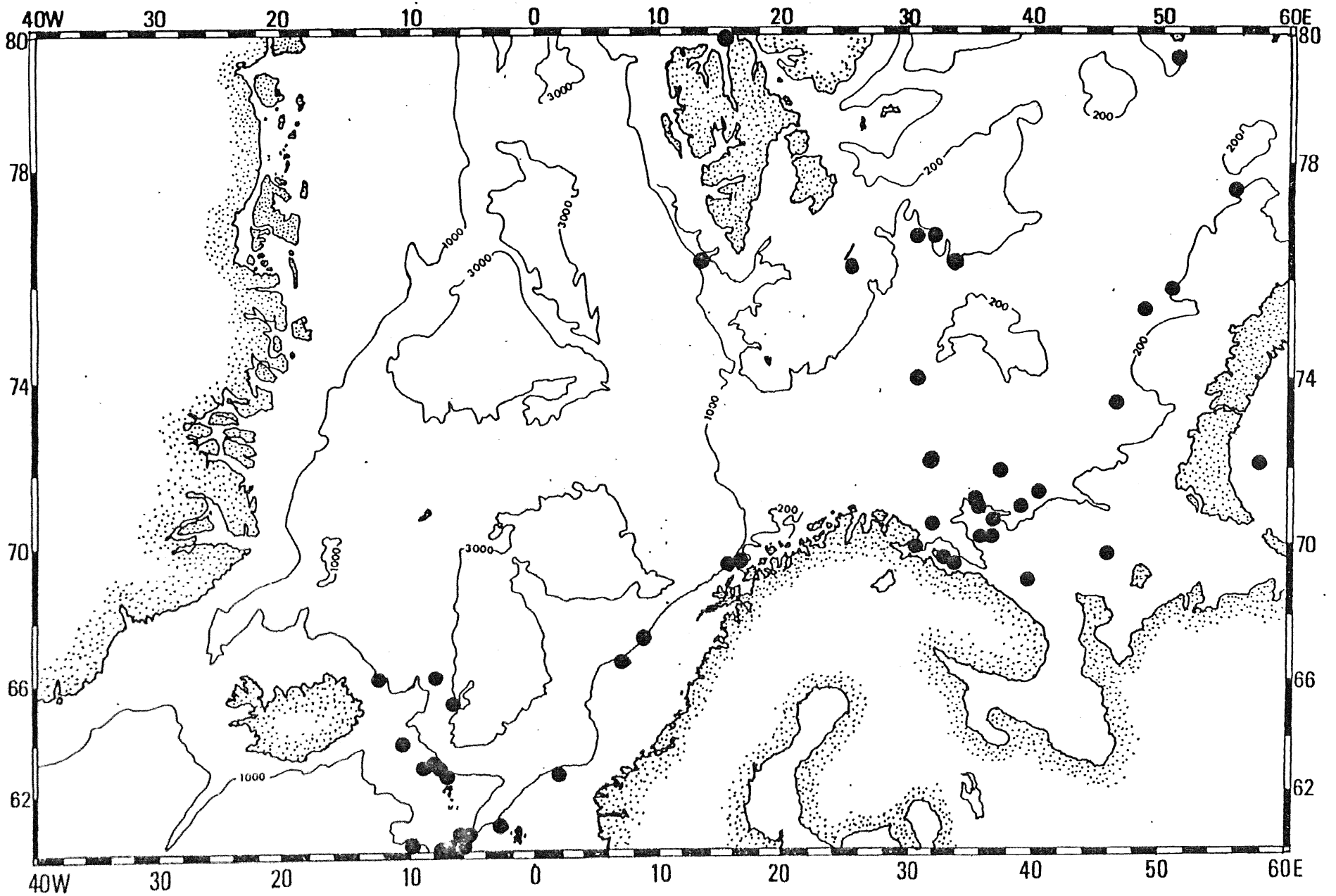
Map 2.8. Nymphon macronyx.



Nymphon macrum Wilson, 1880.

Nymphon macrum Wilson, 1880: 487, Pl 4, Figs 21-28; Sars, 1888: 350; 1891: 89, Pl 9, Figs 2a-g; Norman, 1894: 154; Meinert, 1899: 43; Möbius, 1901: 47; Norman, 1908: 215; Stephensen, 1912: 580; 1913: 396; Schimkewitsch, 1930: 485, Figs 142-145; Stephensen, 1933: 17; 1936: 21; 1937: 5; Hedgpeth, 1948: 193,Figs 13d, 15; Nesis, 1960: 145; Hedgpeth, 1963: 1332.

Nymphon brevicollum Hoek, 1881: 45, Pl 3, Figs 13-15, Pl 15, Figs 12-13; Whiteaves, 1901: 262; Olsen, 1913: 3, Figs 1-9.

Material examined. (See Appendix I).

Description. (fig 2.16).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 1.0 - 1,5 x their diameter, lacking tubercles or setae. Neck cylindrical , length ca 2.5 - 3.0 x its diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with domed crown and 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound sited at ca mid-point of neck. Abdomen pyriform. Posture 40-50° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. Very slender. 1st - 4th essentially cylindrical, 5th very elongate-ovate. Relative segment lengths :- $1 < 4 \triangleq 5 < 3 < 2$, (4 & 5 = 0.5 x 2). Setation, 1st absent, 2nd and 3rd very sparse, 4th sparse, 5th sparse and denser distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 < 5$, (male), $6 < 4 \triangleq 5$ (female). In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.2 x length segment 5.

Ovigeral spine formula :- $\frac{16-18}{7} : \frac{9-11}{8} : \frac{8-9}{9} : \frac{9-10}{10}$ +S.

Chelicerae. Scape cylindrical, sparsely setose with long setae plus fringe of dorsal setae over chela articulation, length ca 0.66 x chela length. Palm essentially cylindrical, non-setose, length ca 0.6 x length of subequal slender fingers. Fingers nonsetose with acute oxeote ends. Dentition uneven on both fingers with mixed needle and peg shaped teeth, tightly packed. Immovable 45 - 60. Movable 70 - 85.

Legs. Generally sparsely setose (Maximum seta length ca 3 - 4 x maximum segment diameter). Relative coxal lengths :- 1 ≃ 3 = 0.33 - 0.5 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length ca 0.75 x length tibia 1. Tibia 1 length ca 0.75 length tibia 2. Tarsus length ca 1.5 x propodus length. Propodus armed with 15 - 20 uniform ventral spines. Terminal claw length ca 0.33 x propodus length. Auxiliary claw lwngth ca 0.66x terminal claw length.

Size ranges (See Table 2.11).

Distribution.

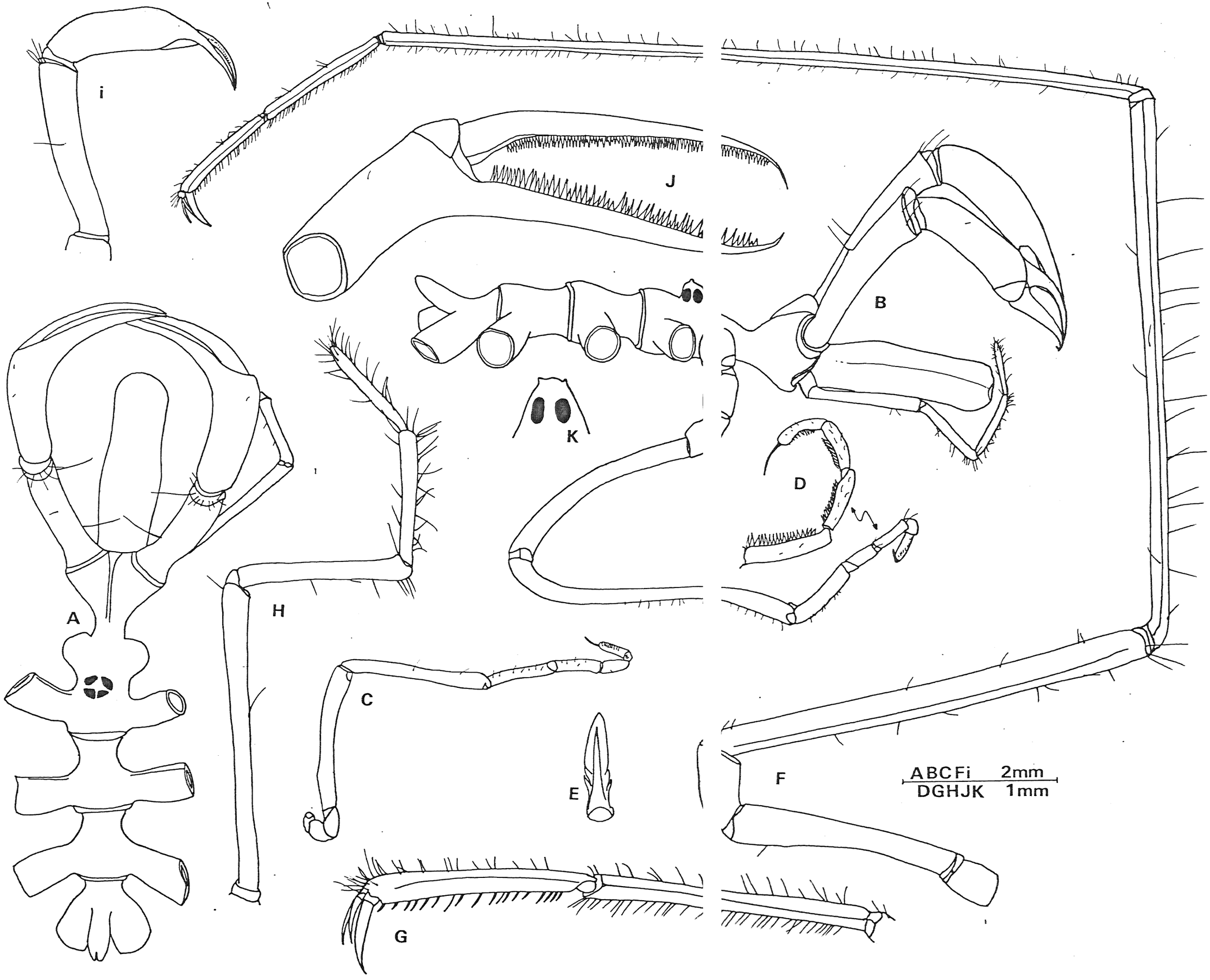
Eastern Arctic. (Map 2.9). The range of this species appears to be restricted to the warm Atlantic water currents. Occurs around Bear Island and in the southwest Barents Sea and also between Iceland and Norway. Rarely found in water shallower than 150 metres.

General. Distributedin the western Atlantic from Cape Farewell, south to the Gulf of Maine. Hedgpeth (1963) thinks this species is an inhabitant of colder north Atlantic water and is not an Arctic species.

Remarks. Nymphon brevicollum Hoek (1881) has been synonymized with this species, Sars (1891) considering it indistinct from Wilson's type specimen.

Table 2.11. Nymphon macrum size ranges. (In millimetres).

	MALE	FEMALE
Trunk	2.80 - 4.00	1.96 - 4.16
Proboscis	1.68 - 2.08	1.48 - 2.16
Abdomen	0.40 - 0.64	0.40 - 0.60
Total palp	2.48 - 4.28	2.32 - 4.56
Cephalic somite length	1.28 - 2.00	1.12 - 2.08
Cephalic somite width	1.20 - 1.92	1.12 - 2.08
Oviger.4	1.20 - 1.92	1.10 - 1.92
Oviger.5	2.28 - 3.03	0.96 - 2.04
Oviger.6	0.56 - 0.92	0.52 - 0.96
Coxa.1	0.64 - 0.72	0.60 - 0.82
Coxa.2	1.20 - 2.24	1.24 - 1.84
Coxa.3	0.56 - 0.80	0.56 - 0.80
Femur	3.36 - 5.68	2.96 - 6.12
Tibia.1	4.70 - 7.48	4.00 - 7.96
Tibia.2	6.15 - 10.72	5.48 - 12.56
Tarsus	1.20 - 1.60	1.16 - 1.64
Propodus	1.04 - 1.20	0.96 - 1.28
Terminal claw	0.48 - 0.56	0.48 - 0.64
Auxiliary claw	0.32 - 0.48	0.32 - 0.48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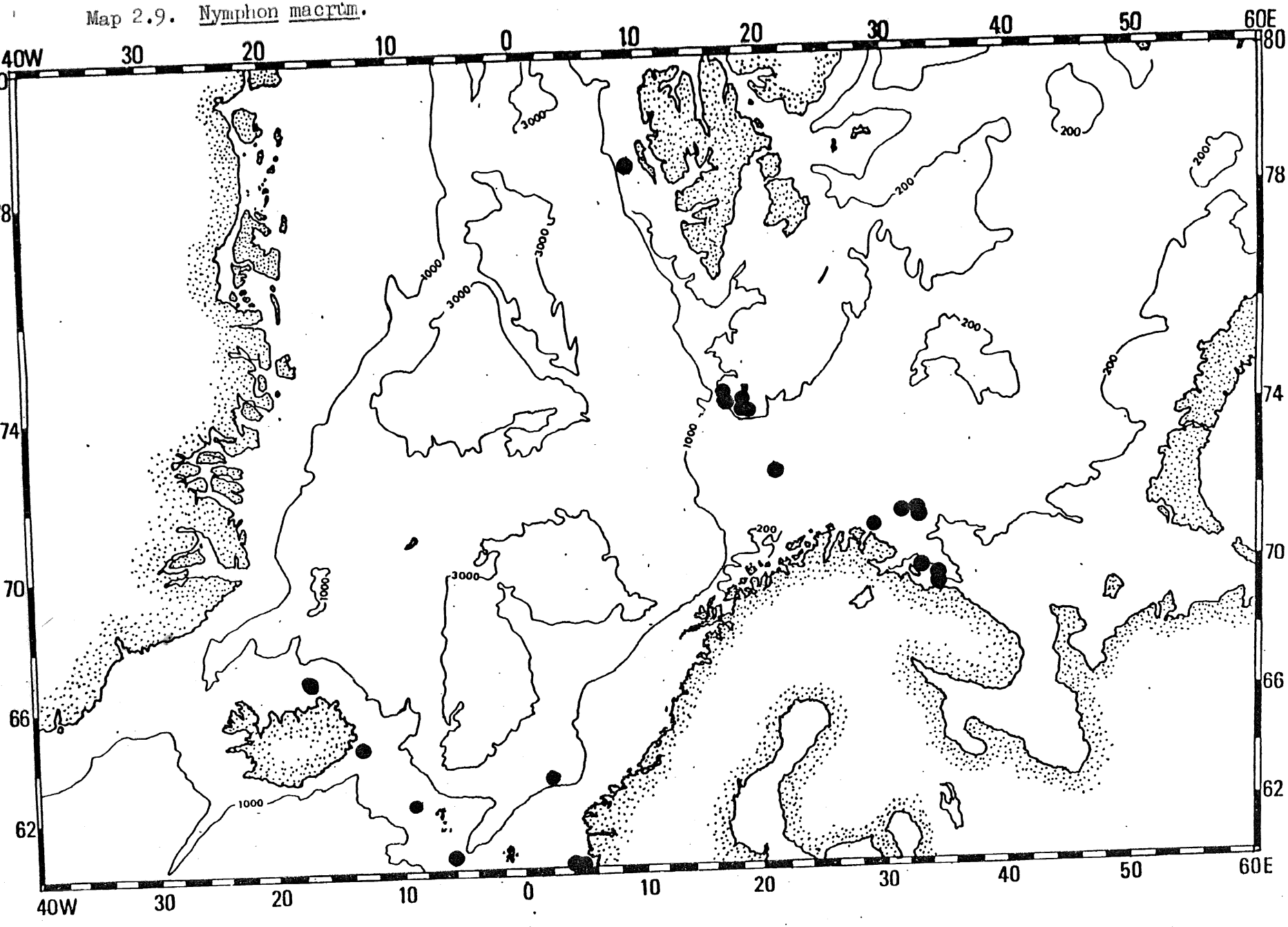
ABCFi 2mm
DGHJK 1mm

Map 2.9. Nymphon macrum.



Nymphon megalops Sars, 1888.

Nymphon megalops Sars, 1888: 336, No 7; 1891: 98, Pl 10, Figs 3a-g; Meinert, 1899: 37; Möbius, 1901: 45; Norman, 1908: 218; Stephensen, 1912: 570; 1913: 397; Schimkewitsch, 1930: 500, Figs 149-152; Stephensen, 1933: 19; 1936: 23; 1937: 6; Hedgpeth, 1943: 87, Fig 2; 1963: 1333.

Material examined. (See Appendix I).

Description. (fig 2.17).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 1.5 - 2.0 x their diameter, lacking tubercles or setae. Neck constricted anteriorly, length ca 1.5 x anterior diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th ovate. Relative segment lengths :- $1 < 4 \triangleq 5 = 0.5 \times 3 < 2$. Setation, 1st absent, 2nd and 3rd sparse, 4th and 5th uniformly microsetose.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 < 5$. In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.33 x length segment 5.

Ovigeral spine formula :- $\frac{23\text{-}27}{7} : \frac{18\text{-}20}{8} : \frac{16\text{-}18}{9} : \frac{14\text{-}20}{10} + S.$

Chelicerae. Scape essentially cylindrical, chela length ca 0.66 x scape length. Palm essentially cylindrical, sparsely microsetose, length ca 1.2 x length of subequal fingers. Base of immovable finger with tuft of sparse setae, movable finger non-setose.

Dentition uniform on both fingers, needle shaped, separated distally by ca 0.5 x basal width. Immovable 18 - 23. Movable 22 - 27.

Legs. generally sparsely setose. Relative coxal lengths :- 1 ≏ 3 = 0.33 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length ca 3.0 - 3.5 x coxa 2 length. Tibia 1 length ca 0.66 length tibia 2. Tarsus and propodus subequal in length. Propodus armed with 6 - 9 uniform ventral spines. Terminal claw length ca 0.25 - 0.33 x propodus length. Auxiliary claw length ca 0.4 x terminal claw length.

Size ranges. (See table 2.12).

Distribution.

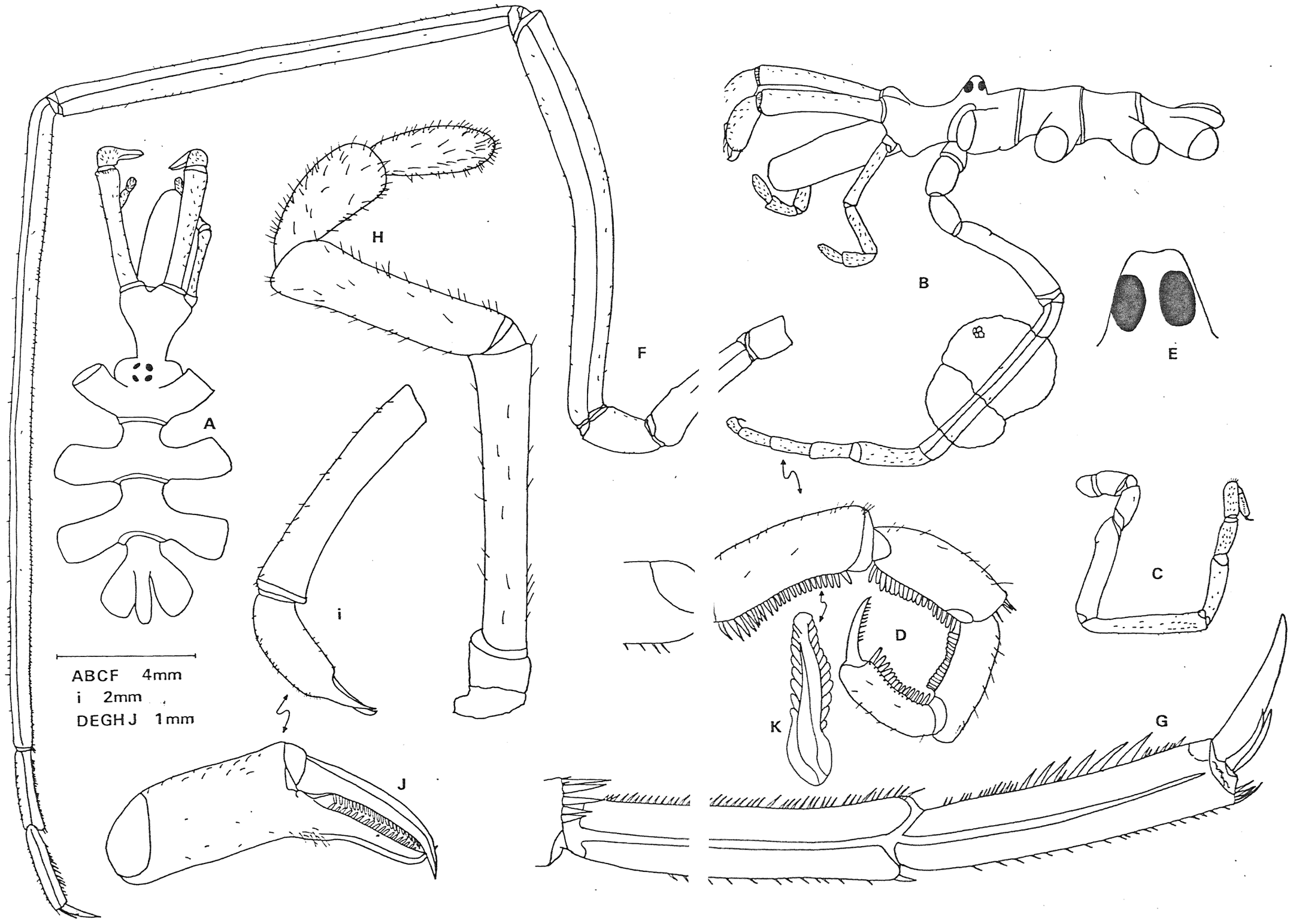
Eastern Arctic. (Map 2.10). Widespread with a patchy abundance. This species is concentrated around the Faroe Channel, West Spitsbergen and Bear Island. A deep water species rare above 300 metres with a mean depth range of 400 - 600 metres. Deepest record is 1200 metres from the Faroe Channel.

General. Recorded from Denmark strait (Meinert, 1899) and Fury and Helca strait - 66.43 N 82.07 W (Hedgpeth, 1963). The latter record is from 55 metres, which may indicate that within the American Arctic the species has a shallower distribution.

Remarks. Taxonomically a stable species.

Table 2.12 *Nymphon megalops* size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	6.27 - 7.52	6.24 - 7.04	5.08 - 6.36
Proboscis	2.72 - 3.2	2.72 - 3.20	2.36 - 3.08
Abdomen	0.80 - 0.96	0.80 - 0.96	0.24 - 0.32
Total palp	3.36 - 4.64	3.20 - 5.28	2.22 - 3.72
Cephalic somite length	3.04 - 3.68	3.20 - 4.00	2.56 - 3.20
Cephalic somite width	2.72 - 3.76	2.73 - 3.84	2.56 - 3.40
Oviger.4	2.80 - 3.04	1.92 - 3.04	
Oviger.5	4.48 - 5.52	2.16 - 3.68	
Oviger.6	1.60 - 2.08	0.96 - 1.92	
Coxa.1	1.12 - 1.60	0.96 - 1.60	0.96 - 1.28
Coxa.2	3.68 - 4.32	3.36 - 3.52	2.40 - 3.20
Coxa.3	1.28 - 1.60	1.28 - 2.08	1.12 - 1.28
Femur	10.40 - 12.00	8.16 - 14.08	7.32 - 8.68
Tibia.1	10.72 - 13.28	9.76 - 16.32	8.96 - 10.40
Tibia.2	15.04 - 19.84	13.3 - 26.10	13.6 - 16.8
Tarsus	2.24 - 2.72	2.08 - 2.76	1.60 - 2.08
Propodus	2.24 - 2.88	2.24 - 2.40	1.44 - 2.08
Terminal claw	0.96 - 1.12	0.96 - 1.28	0.64 - 0.96
Auxiliary claw	0.80 - 0.96	0.48 - 0.56	0.24 - 0.40


A
H
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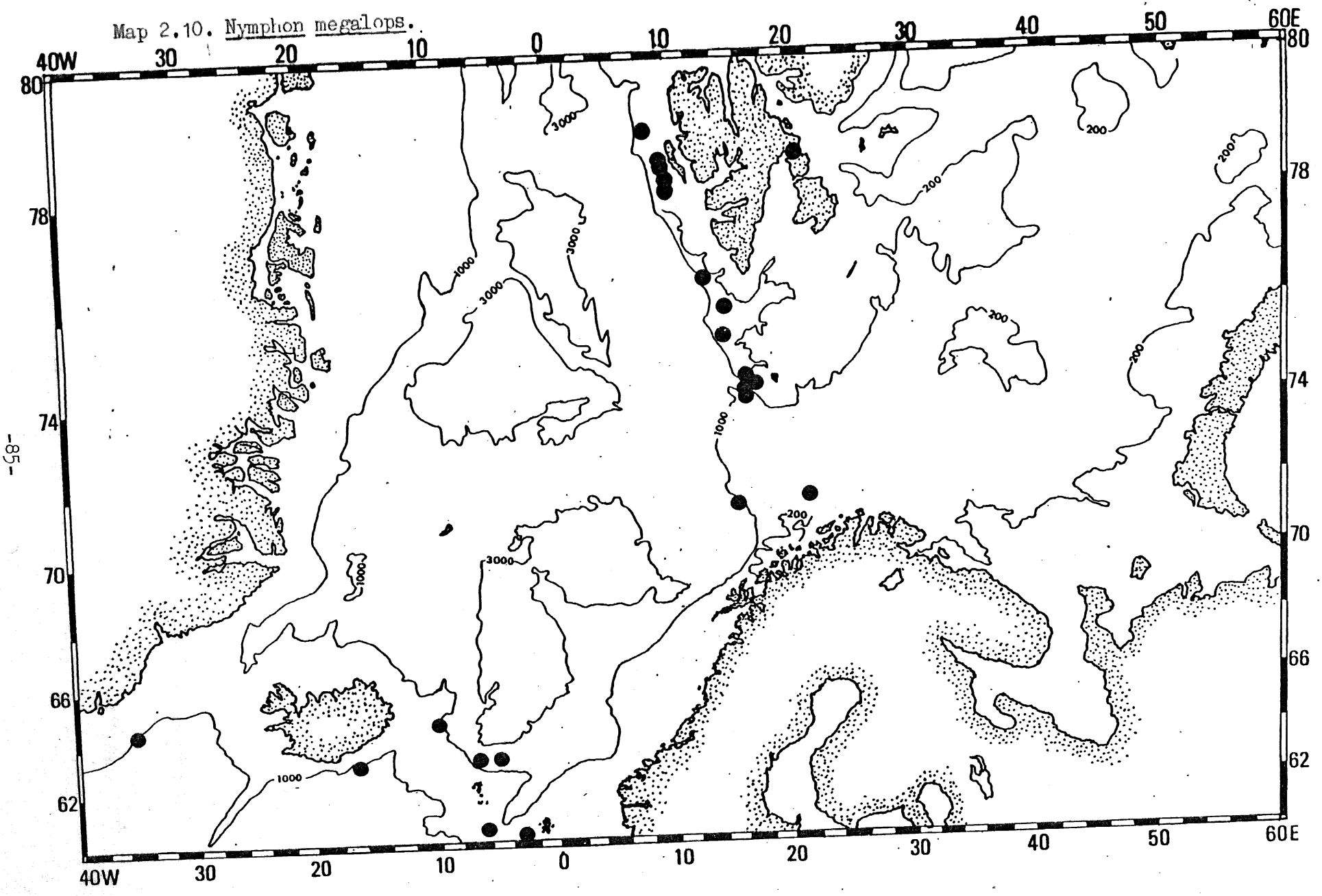
C
D
K
G
i
J
ABCF 4mm
i 2mm
DEGHJ 1mm

Map 2.10. Nymphon megalops.



Nymphon microrhynchum Sars, 1888.

Nymphon microrhynchum Sars, 1888: No 20; 1891: 71, Pl 7, Figs 1a-g; Norman, 1908: 212; Appellöf, 1916: 17; Schimkewitsch, 1930: 443; Stephensen, 1933: 13; 1936: 13; 1943: 21; Hedgpeth, 1963: 1330.

Nymphon longicarse ; Hansen, 1887: 196, Pl 8, Fig 7.

Material examined. (See Appendix I).

Description. (fig 2.18).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 1.5 - 2.0 x their proximal diameter, lacking tubercles, very sparsely setose on dorsodistal edges. Neck cylindrical, length ca 2.0 - 2.5 x diameter. Centre of ocular tubercle situated an anterior margin of 1st lateral processes, conical, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture ca 70° from horizontal.

Proboscis. Length ca 0.75 x cephalic somite length. TYPE J' - B'".

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 4 < 5 < 2 \triangleq 3$. Setation, 1st absent, 2nd and 3rd sparse, 4th heavy ventrally, 5th heavy ventrally and distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$. In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.3 x length segment 5.

Ovigeral spine formula :- $\frac{12-13}{7} ; \frac{10-11}{8} ; \frac{8-9}{9} ; \frac{9-10}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose, length ca 1.5 x chela length. Palm essentially cylindrical, sparsely

microsetose, length ca 2.0 x immovable finger length. Fingers stout, base of immovable finger with tuft of microsetae, movable finger non-setose. Immovable finger length ca 0.66 x movable finger length. Fingers with oxeote ends. Dentition uniform on both fingers, minute, closely packed, needle shaped. Both fingers with 10 - 15 teeth.

Legs. Generally sparsely setose. Relative coxal lengths :- 1 3 = 0.33 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length, ca 0.75 x tibia 2 length. Tarsus length ca 1.3 x propodus length. Propodus armed with 4 - 5 ventral spines, longest sited proximally. Terminal claw length ca 0.4 x propodus length. Auxiliary claw length ca 0.66 x terminal claw length.

Size ranges. (See Table 2.13).

Distribution.

Eastern Arctic. (Map 2.11). Very rare, the only records are from east Spitsbergen, eastern Greenland and Bear Island. It would appear to be a species of colder water. Recorded at depths of between 100 - 250 metres.

General. Ranges in the east to the White and Kara Seas (Schimkewitsch, 1930) and in the west to Cornwallis Island - 74.37 N 94.13 W (Hedgpeth, 1963), although he is not wholly positive about his identification.

Remarks. The record of N.longitarse Hansen (1887) has been synonymized with this species. In addition, Stephensen (1933) thinks that this species can be confused with N.longitarse Krøyer (1844). I agree with the opinion of Hedgpeth (1963) that the species bears little resemblence to Nymphon longitarse Kroyer.

Its nearest relative appears to be N.grossipes, having similarities in the shape of the ocular tubercle and the form of the terminal leg segments of the walking leg. Owing to the rare nature of this species only one adult female and one adult male, bearing ovigeral egg masses, were measured.

Table 2.13 Nymphon microrynchum size ranges. (In millimetres).

	MALE	FEMALE
Trunk	3.57	3.62
Propodus	1.09	1.12
Abdomen	0.19	0.24
Total palp	1.62	1.68
Cephalic somite length	1.55	1.62
Cephalic somite width	1.52	1.62
Oviger.4	1.81	1.25
Oviger.5	1.82	1.25
Oviger.6	0.65	0.54
Coxa.1	0.65	0.68
Coxa.2	1.81	1.62
Coxa.3	0.75	0.64
Femur	4.06	4.52
Tibia.1	4.25	4.82
Tibia.2	5.97	6.40
Tarsus	1.66	1.72
Propodus	1.06	1.12
Terminal claw	0.56	0.56
Auxiliary claw	0.28	0.32

B

E

C

D

ABCF 2 mm
DEGHi 1mm

i

H

G

A

F

Nymphon serratum Sars, 1879.

Nymphon serratum Sars, 1879: Vol 4, 471; Hoek, 1881: 16, Pl 1, Figs 24-28, Pl 2, Fig 24; Hansen, 1887: 161, Pl 18, Fig 2; Sars, 1891: Pl 10, Figs 2a-h; Meinert, 1899: 37; Möbius, 1901: 45; Norman, 1908: 218; Appellöf, 1910: 6; Stephensen, 1912: 552, 574, 577; 1913: 395; Schimkewitsch, 1930: 496, Figs 146-148; Stephensen, 1933: 146; Losina-Losinsky, 1935: 25; Stephensen, 1936: 23; 1937: 5; 1943: 26; Hedgpeth, 1943: 87; Nesis, 1960: 146; Hedgpeth, 1963: 1333.

Material examined. (See Appendix I).

Description. (fig 2.19).

Trunk. Three complete intersegmental articulations, posterior pointing dorsomedian projections sited at posterior of somites 1 - 3. Lateral processes essentially cylindrical, separated by ca 0.5 - 1.0 x their proximal diameter, lacking tubercles, setose sparsely on distal edge. Neck constricted anteriorly, length ca 1.5 x anterior diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with domed crown possessing 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th ovate. Relative segment lengths :- $1 < 4 \triangleq 5 < 3 = 0.66 \times 2$. Setation, 1st absent, 2nd sparse, 3rd, 4th and 5th heavy microsetose.

Adult oviger. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 < 5$. In female, segment 6 length ca 0.5 x length segment 5. In male, segment 6 length ca 0.25 - 0.33 x length segment 5.

Ovigeral spine formula :- $\frac{23\text{-}25}{7} : \frac{15\text{-}19}{8} : \frac{17\text{-}18}{9} : \frac{15\text{-}19}{10}$ + S.

Chelicerae. Scape essentially cylindrical, sparsely setose dorsally. Chela length ca 0.7 x scape length. Palm essentially cylindrical, sparsely microsetose, length ca 1.2 x length of subequal fingers. Base of immovable finger with tuft of sparse setae, movable finger non-setose. Fingers with oxeote ends. Dentition uniform on both fingers, needle shaped, separated distally by ca 0.5 x basal width. Immovable 20 - 23. Movable 21 - 25.

Legs. Generally sparsely microsetose. Relative coxal lengths :- 1 ≙ 3 = 0.5 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length, ca 0.5 - 0.6 x length tibia 2. Tarsus and propodus subequal in length. Propodus armed with 9 - 11 ventral spines, longest sited distally. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.33 - 0.5 x terminal claw length.

Size ranges (See table 2.14).

Distribution.

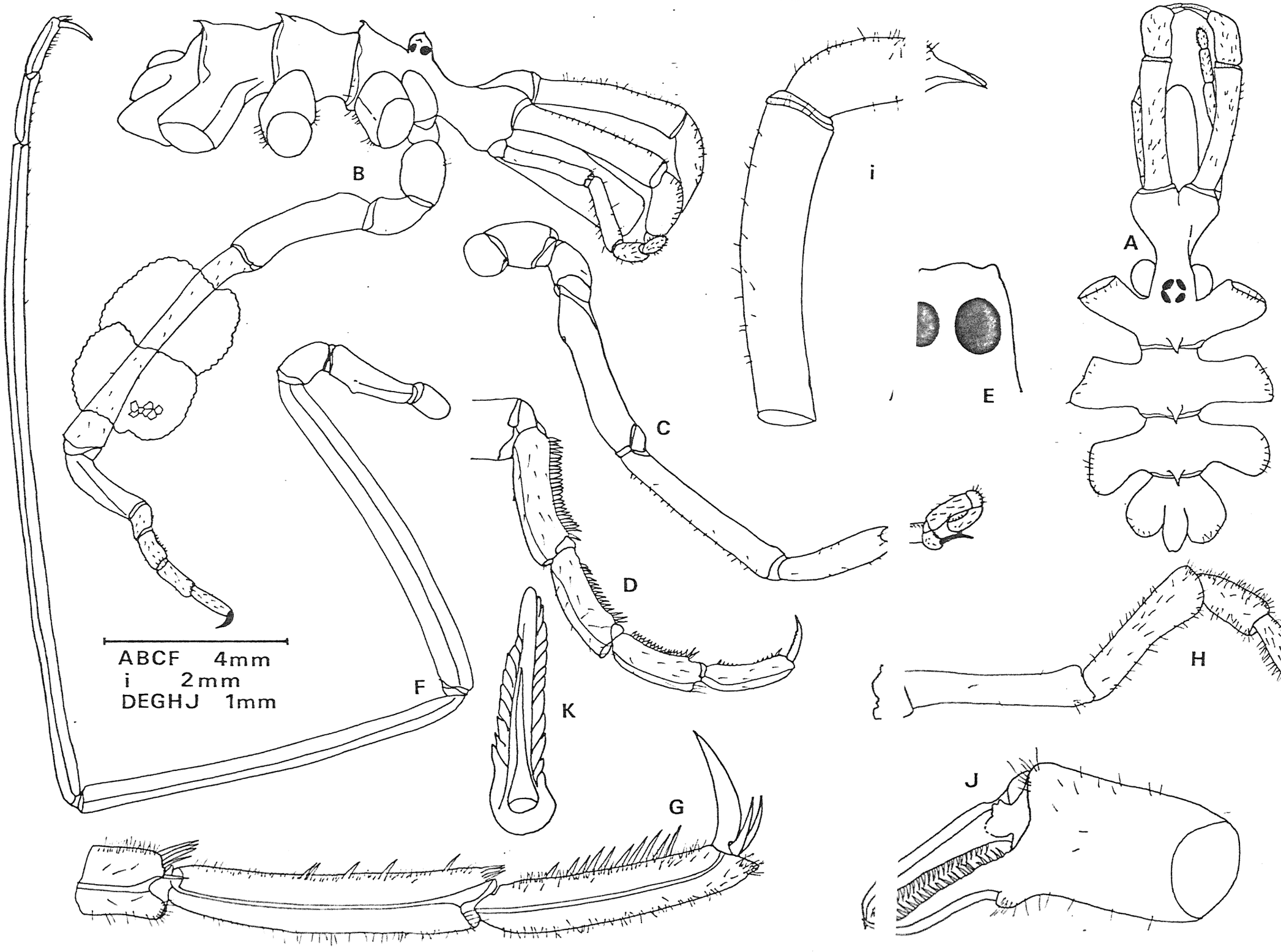
Eastern Arctic. (Map 2.12). A common although not abundant species, reported from Bear Island, West Spitsbergen, Iceland and the Barents Sea. A shallow water species, rare below 400 metres, with a mean depth range of 100 - 250 metres, although has been recorded in the Denmark strait at 1400 metres (Meinert, 1899).

General. Prior to Hedgpeth (1963) the known westerly range of this species was the Denmark strait; however, this has now been extended west of the Foxe basin to Repulse Bay- 66.28 N 86.12 W. To the east it has been recorded as far as the Kara Sea. Depth range similar to that in the Eastern Arctic.

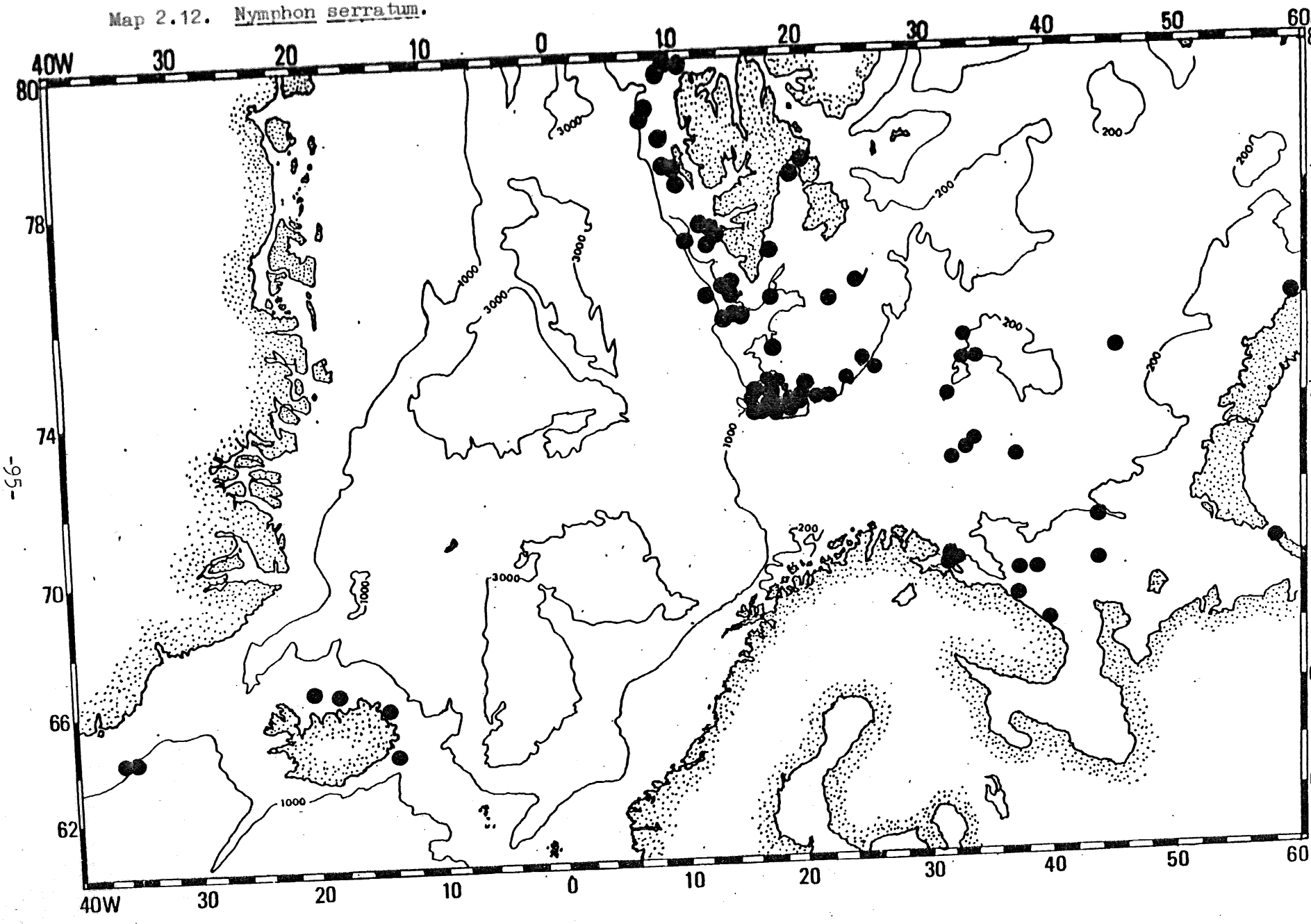
Remarks. Taxonomically stable. This species is clearly identified by the row of backward pointing dorsolateral projections along the trunk.

Table 2.14. Nymphon serratum size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	6.40 - 7.20	6.72 - 9.60	3.83 - 3.72
Proboscis	2.56 - 3.04	2.40 - 4.32	2.08 - 3.04
Abdomen	0.96 - 1.12	0.64 - 1.60	0.32 - 0.63
Total palp	3.20 - 5.12	4.60 - 6.08	1.93 - 3.84
Cephalic somite length	3.20 - 3.62	3.20 - 4.96	2.24 - 3.20
Cephalic somite width	3.20 - 3.52	2.40 - 4.64	1.90 - 2.88
Oviger.4	2.48 - 3.36	2.64 - 3.84	
Oviger.5	3.68 - 6.40	2.96 - 4.56	
Oviger.6	1.12 - 2.24	1.44 - 2.32	
Coxa.1	1.28 - 1.44	0.96 - 1.92	0.80 - 1.28
Coxa.2	3.68 - 4.32	3.04 - 4.96	2.08 - 3.52
Coxa.3	1.44 - 1.52	1.44 - 2.24	0.80 - 1.44
Femur	8.96 - 9.28	8.32 - 16.32	5.76 - 8.80
Tibia.1	10.88 - 11.52	9.28 - 19.04	7.68 - 10.42
Tibia.2	12.64 - 16.16	13.76 - 31.50	8.32 - 14.88
Tarsus	2.30 - 2.72	2.08 - 4.00	1.44 - 2.24
Propodus	2.08 - 2.40	2.08 - 3.20	1.12 - 2.24
Terminal claw	0.96 - 1.32	0.80 - 1.44	0.48 - 1.12
Auxiliary claw	0.24 - 0.56	0.32 - 0.56	0.16 - 0.32


B
i
A
C
E
D
ABCF 4mm
i 2mm
DEGHJ 1mm
F
K
H
G
J

Map 2.12. Nymphon serratum.



Nymphon sluiteri Hoek, 1881.

Nymphon sluiteri Hoek, 1881: 18, Pl 2, Figs 30-34; Hansen, 1887: 166, Pl 18, Fig 5; Sars, 1891: 73, Pl 7, Figs 2a-g; Carpenter, 1898: 630; Meinert, 1899: 36; Möbius, 1901: 44; Norman, 1908: 213; Appellöf, 1910: 6; Stephensen, 1912: 14; 1913: 398; Appellöf, 1916: 5; Schimkewitsch, 1930: 425, Figs 113-117; Stephensen, 1933: 14; Losina-Losinsky, 1935: 34; Stephensen, 1936: 14; Hedgpeth, 1943: 86; Stephensen, 1943; 22; Nesis, 1960: 144; Hedgpeth, 1963: 1331.

Material examined. (See Appendix I).

Description. (fig 2.20).

Trunk. Three complete intersegmental articulations. Lateral processes posteriorly positioned on somite, broadening distally, separated by ca 0.5-1.0 x their proximal diameter, lacking tubercles or setae. Neck essentially cylindrical, length ca 1.0 - 1.5 x diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, conical, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture 45° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 4 < 5 \triangleq 2 < 3$. Setation, 1st absent, 2nd and 3rd very sparse, 4th heavy microsetose ventrally, 5th heavy microsetose ventrally and distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$. In female, length 6th segment ca 0.5 x length segment 5. In male, length 6th segment ca 0.33 - 0.4 x length segment 5. In male 5th segment distally bulbous.

Ovigeral spine formula :- $\frac{19\text{-}22}{7} : \frac{18\text{-}19}{8} : \frac{17\text{-}18}{9} : \frac{16\text{-}19}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose, length subequal with chela. Palm essentially cylindrical, sparsely setose, length subequal with movable finger. Movable finger arcuate, non-setose. Immovable finger gently sigmoid with base covered with tuft of sparse setae. Immovable finger length ca 0.75 x movable finger length. Fingers with gradually tapering oxeote ends. Dentition larger on movable finger, uniform needle shaped, separated distally on both fingers by ca 0.5 x basal width. Immovable 38 - 40. Movable 43 -45.

Legs. Generally sparsely setose (maximum setae length subequal with maximum segment diameter). Relative coxal lengths :- 1 ≏ 3 = 0.25 - 0.3 x 2. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length. Tibia 2 slightly curved, length ca 1.2 x tibia 1 length. Tarsus and propodus subequal in length. Propodus bearing 10 - 14 ventral spines, longest sited proximally. Terminal claw arcuate, gradually tapering, length ca 0.9 x length of propodus. Auxiliary claw length ca o.1 x terminal claw length.

Size ranges (See table 2.15).

Distribution.

Eastern Arctic. (Map 2.13). Not a particularly abundant species although widespread on the Barents Sea and West Spitsbergen shelves at depths between 50 - 500 metres. The species has also been recorded between the Faroes and Jan Mayan where it occurs at a greater depth between 700 - 1435 metres.

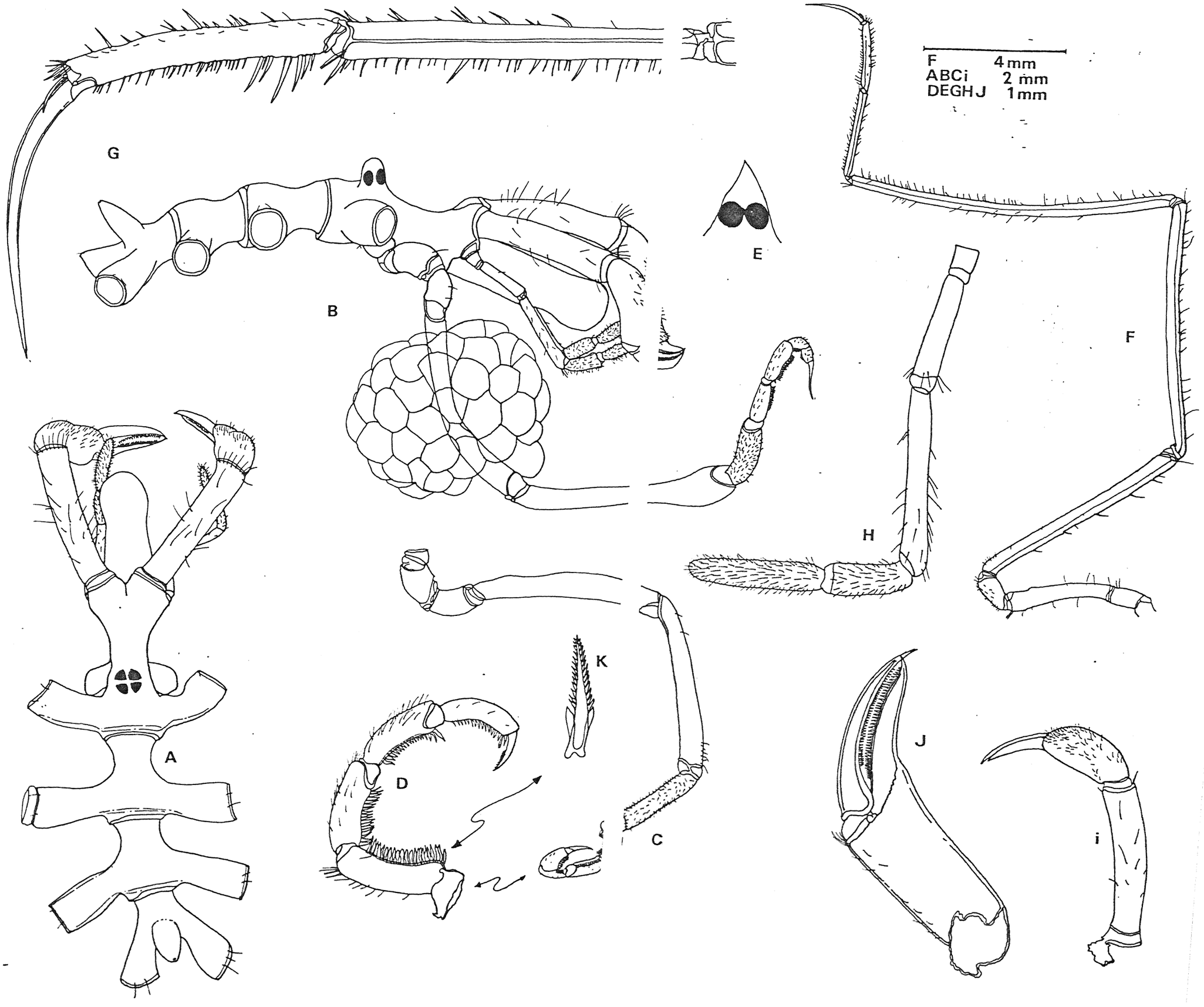
General. There are some doubts as to whether this species has a circumpolar distribution. Stephensen (1933) thinks that there is little doubt about this whereas Hedgpeth (1963) disagrees, stating

that "it possesses a similar distribution to Nymphon hirtipes, being a high Arctic form but absent from the Pacific Arctic."

Remarks. A stable species taxonomically, it is easily recognized by the very long arcuate terminal claws.

Table 2.15. Nymphon sluiteri size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	3.38 - 5.28	3.84 - 5.33	2.60 - 3.90
Proboscis	1.56 - 2.24	1.12 - 2.24	1.30 - 1.43
Abdomen	0.93 - 0.80	0.64 - 0.78	0.54 - 0.72
Total palp	2.66 - 3.36	3.36 - 3.96	1.24 - 2.77
Cephalic somite length	1.82 - 2.56	1.92 - 2.86	1.43 - 1.69
Cephalic somite width	1.95 - 2.88	2.08 - 2.73	1.56 - 1.82
Oviger.4	3.04	2.09	
Oviger.5	3.04	1.90	
Oviger.6	1.06	0.95	
Coxa.1	1.28 - 1.65	0.96 - 1.04	0.65 - 0.78
Coxa.2	1.82 - 3.20	2.40 - 2.73	1.43 - 2.70
Coxa.3	1.12 - 1.78	0.80 - 1.04	0.65 - 0.78
Femur	4.42 - 6.88	5.92 - 7.80	3.38 - 5.46
Tibia.1	4.49 - 7.84	6.72 - 7.80	3.90 - 6.50
Tibia.2	6.73 - 10.08	8.32 - 10.90	5.33 - 8.60
Tarsus	1.95 - 3.04	1.92 - 2.99	1.56 - 2.21
Propodus	1.43 - 1.92	1.44 - 1.95	1.30 - 1.43
Terminal claw	1.24 - 1.76	1.28 - 1.69	1.04 - 1.17
Auxiliary claw	0.07 - 0.16	0.19 - 0.21	0.03 - 0.07


F 4mm
ABCi 2 mm
DEGHJ 1mm
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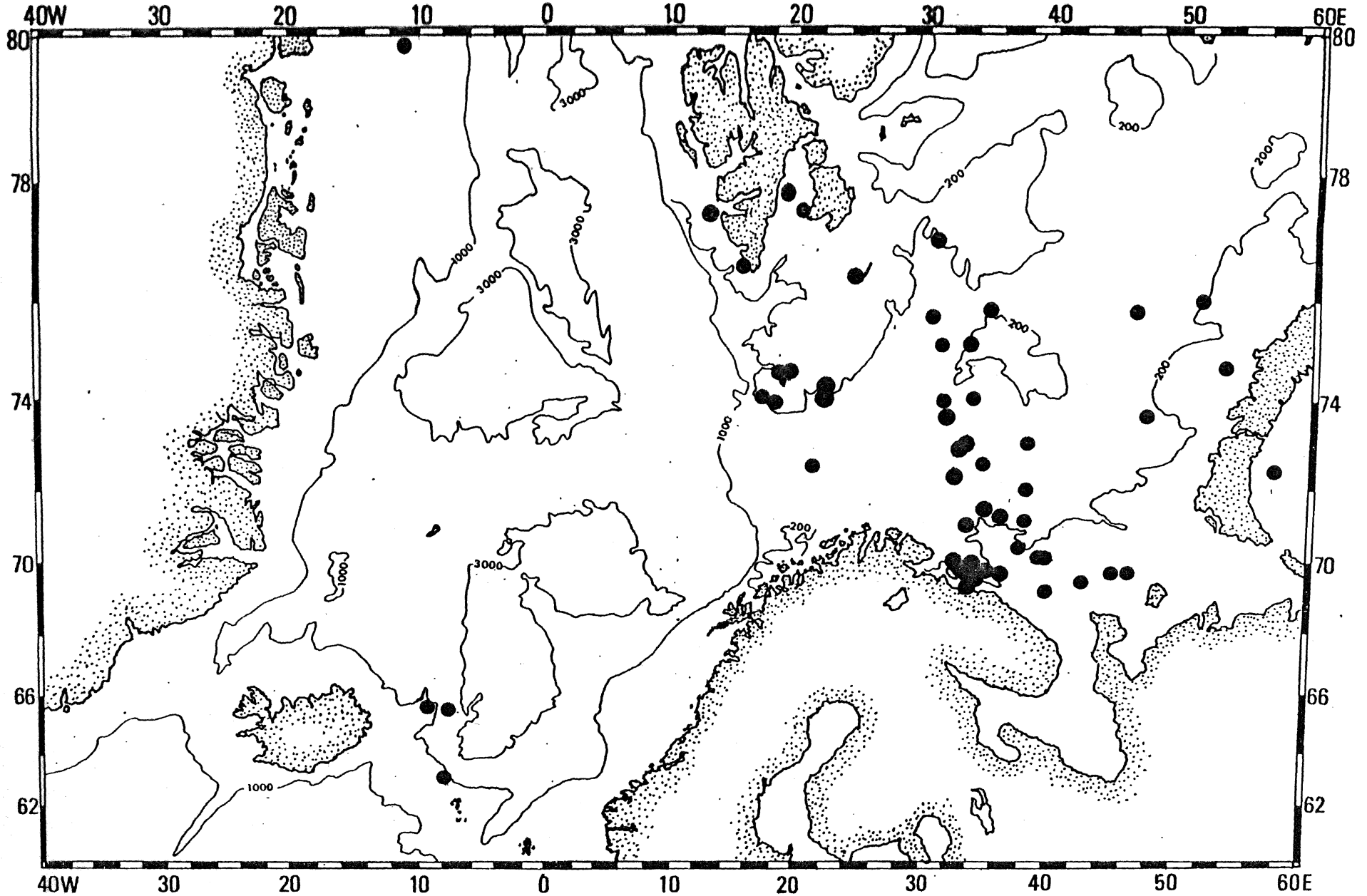
Map 2.13. Nymphon sluiteri.



Nymphon strömi Krøyer, 1844.

Nymphon strömi Krøyer, 1844: 111; 1849: Pl 35, Figs 3a-f; Norman, 1868: 301; Wilson, 1878: 17, Pl 6, Figs 1a-h; Hoek, 1881: 9; Hansen, 1887: 163, Pl 18, Fig 3; Adlerz, 1888: 1, Pl 1, Figs 1-3; Sars, 1891: 80, Pl 8, Figs 2a-k; Meinert, 1899: 38; Norman, 1908: 214; Appellöf, 1910: 6; Stephensen, 1913: 392; Appellöf: 1916:8, Figs 1-4; Schimkewitsch, 1930: 451, Figs 128-131; Stephensen, 1933: 16; 1936: 15, Fig 1; 1937: 4; 1943: 23; Hedgpeth, 1948: 190; Nesis, 1960: 144; Hedgpeth, 1963: 1331.

Nymphon gracilipes Heller, 1875: 609, Pl 4, Fig 15, Pl 5, Figs 1-2; Sars, 1891: 83, Pl 8, Figs 3a-g.

Nymphon giganteum Goodsir, 1844: 114, Pl 3; Norman, 1896: 301; Whiteaves, 1872: 347; Verrill, 1874: 493; Norman, 1908: 214.

Nymphon Jan-Mayanensis Appellöf, 1907: 9.

Material examined. (See Appendix I).

Description. (fig 2.21).

Trunk. Three complete intersegmental articulations. Lateral processes essentially cylindrical, separated by ca 0.5 - 0.75 x their proximal diameter, lacking tubercles, sparsely setose distally. Neck narrowing distally, length ca 0.5 x distal diameter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture ca 20° from horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th elongate-ovate. Relative segment lengths :- $1 < 4 \simeq 5 < 2 \simeq 3$. Setation, 1st absent, 2nd and 3rd very sparse, 4th sparse ventrally, 5th sparse ventrally

and distally.

Adult ovigers. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 \triangleq 5$. In female, segment 6 length ca 0.6 x length segment 5. In male, segment 6 length ca 0.75 x length segment 5.

Ovigeral spine formula :- $\frac{24\text{-}28}{7} : \frac{16\text{-}20}{8} : \frac{15\text{-}18}{9} : \frac{16\text{-}20}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely microsetose, length ca 0.7 - 0.8 x chela length. Palm essentially cylindrical, sparsely microsetose, length subequal to gently arcuate fingers. Fingers subequal with acute oxeote ends. Dentition uniform, needle shaped. Immovable finger dentition length ca 2.0 x movable finger dentition length. Immovable 30 - 32. Movable 40 - 44.

Legs. Generally heavily microsetose. Relative coxal lengths :- $1 \triangleq 3 = 0.3 \times 2$. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur length < tibia 1 length < tibia 2 length (femur length ca 0.5 x length tibia 2). Propodus length ca 0.8 x tarsus length. Propodus armed with 50 - 60 uniform ventral spines Terminal claw variable in length, ca 0.5 - 0.8 x length of propodus. Auxiliary claw length ca 0.2 - 0.3 x terminal claw length.

Size ranges. (See table 2.16).

Distribution.

Eastern Arctic. (Map 2.14). An abundant and widespread species. Recorded from Spitsbergen, Bear Island, Faroe Channel, Iceland and Jan Mayan, with a mean depth of between 100 - 400 metres.

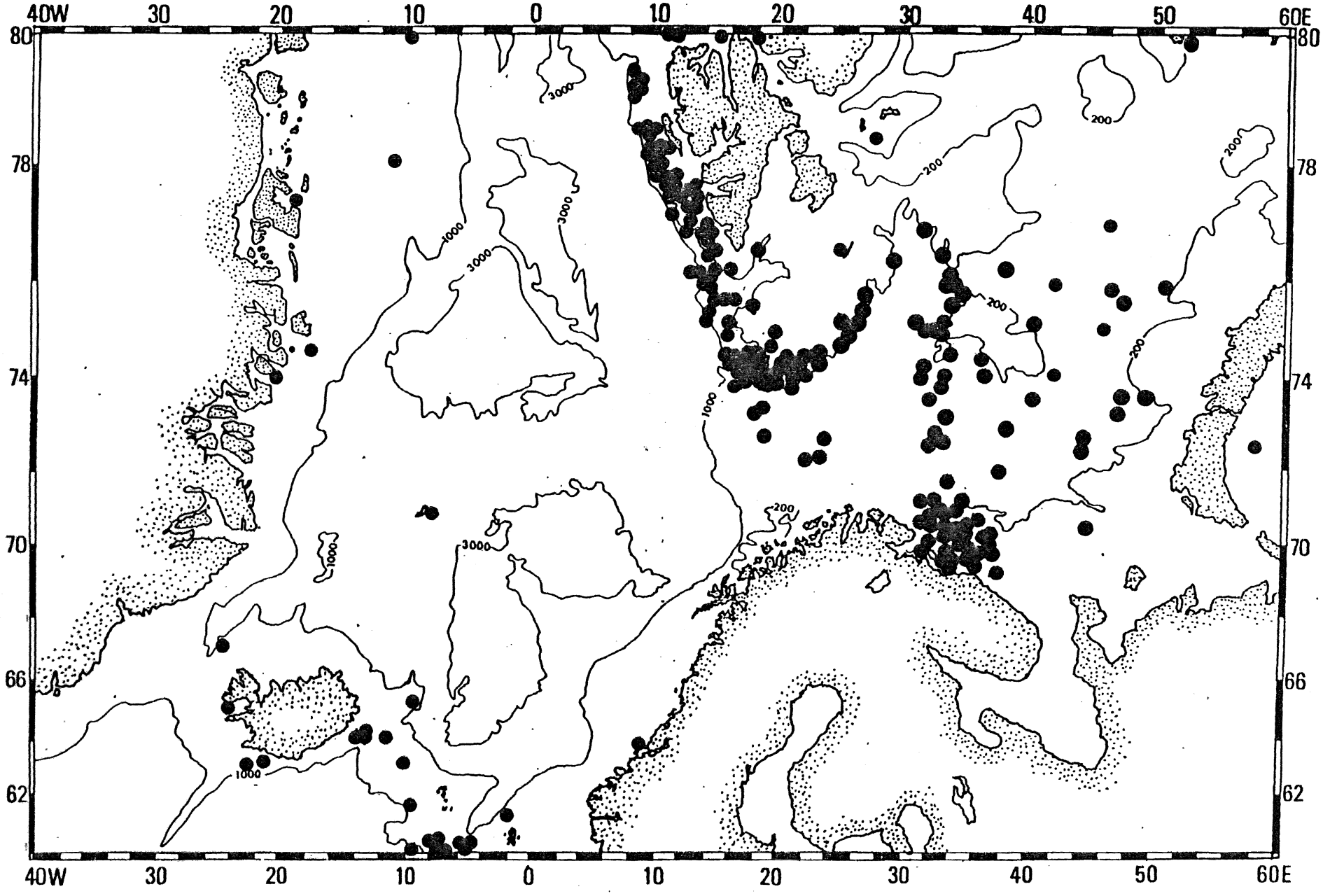
General. The species is spread throughout the northern North Sea, Kara Sea and along the northeast coast of America as far as Cape Cod. Its western limit is 82° west (Fury and Helca strait). Hedgpeth (1963) thinks the distribution similar to that of Nymphon hirtipes and N. sluiteri but with a more southerly reach.

Remarks. This is the largest species of Eastern Arctic Nymphon and also one of the most abundant. The species exhibits considerable variation in the proportions of the terminal leg segments, this variation having led to the species being fragmented (Goodsir, 1844; Heller, 1875; Sars, 1891). Stephensen (1933) states that N. strömi should not be split, but adds that N. gracilipes Sars (1891) has a more northerly distribution than N. strömi.

Table 2.16. Nymphon strömi size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	6.56 - 9.76	7.04 - 8.96	4.00 - 8.64
Proboscis	3.68 - 5.28	3.52 - 5.12	2.56 - 3.84
Abdomen	1.12 - 1.56	1.28 - 1.54	0.80 - 1.12
Total palp	6.40 - 10.80	8.24 - 10.24	4.16 - 7.86
Cephalic somite length	3.36 - 3.96	4.00 - 4.80	2.40 - 4.80
Cephalic somite width	3.36 - 4.48	3.84 - 4.64	1.92 - 4.00
Oviger.4	4.74 - 5.04	3.76 - 3.92	
Oviger.5	4.80 - 5.12	3.76 - 3.92	
Oviger.6	3.04 - 3.92	2.40 - 2.56	
Coxa.1	1.44 - 1.92	1.86 - 1.92	0.80 - 1.44
Coxa.2	3.20 - 5.76	4.00 - 5.28	2.40 - 4.32
Coxa.3	1.60 - 2.56	1.76 - 2.08	1.12 - 1.76
Femur	9.92 - 15.20	12.00 - 15.84	6.04 - 11.52
Tibia.1	12.16 - 17.12	14.56 - 18.88	7.52 - 14.56
Tibia.2	18.24 - 28.70	22.80 - 29.80	9.60 - 22.60
Tarsus	2.72 - 4.16	3.52 - 4.16	1.76 - 3.36
Propodus	2.24 - 3.20	2.88 - 3.04	1.52 - 3.36
Terminal claw	0.96 - 1.76	0.96 - 1.28	0.64 - 1.32
Auxiliary claw	0.16 - 0.56	0.32 - 0.40	0.08 - 0.24

Map.2.14. Nymphon strömi.



Nymphon tenellum Sars, 1888.

Chaetonymphon tenellum Sars, 1888: 353, No 35; 1891: 109, Pl 12, Figs 1a-h; Möbius 1901: 48; Norman, 1908: 220; Stephensen, 1912: 581; 1913: 398.

Nymphon tenellum; Hedgpeth, 1948: 85.

Chaetonymphon spinosissimum Norman, 1894: 154; 1908: 219; Stephensen, 1913: 400; 1933: 6; 1936: 6; 1937: 1; 1943: 14, Fig 4.

Nymphon spinosissimum; Hedgpth, 1948: 183, Figs 9, 10a, 11a; 1963: 1327.

Chaetonymphon spinosum; Sars, 1888: 353; 1891: 108, Pl 12, Fig 3a-i; Möbius, 1901: 48 (partim); Schimkewitsch, 1930: 335, Figs 81-87 (partim).

Nymphon spinosum; Meinert, 1899: 44 (partim).

nec Nymphon spinosum Goodsir 1842: 139, Pl 3, Fig 3. = Nymphon hirtum Fabricius, J.C.

nec Nymphon pallenoides; Wilson, 1878: 254, Pl 3, Fig 14; Verrill, 1885: 561. = Nymphon hirtum Fabricius, J.C.

nec Nymphon tenellum; Meinert, 1899: 45. = Nymphon spinosissimum Norman and Nymphon macronyx Sars.

Material examined.(See Appendix I).

Descriptions.

Robust morph. (fig 2.22).

Trunk. Three complete intersegmental articulations, comb of setae on ridges of chela insertions. Lateral processes essentially cylindrical, separated by ca 0.25 - 0.33 x their proximal diameter, lacking tubercles, dorsodistally setose. Neck thick, length ca 0.2 x diameter. Centre of ocular tubercle situated at anterior margin

of 1st lateral processes, cylindrical with domed crown and 2 dorsolateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture horizontal.

Proboscis. Length subequal to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th ovate. Relative segment lengths :- 1 < 5 < 4 < 3 < 2. Setation, 1st and 2nd absent, 3rd, 4th and 5th uniform heavy (maximum seta length ca 1.5 - 2.0 x maximum segment diameter).

Adult oviger. Relative segment lengths :- $1 \triangleq 2 \triangleq 3 \triangleq 7 \triangleq 8 \triangleq 9 \triangleq 10 < 6 < 4 < 5$.

Segment 4 of both sexes possesses proximal nodule. In female, segment 5 is uniform in diameter. In male, segment 5 with heavily setose distal bulb.

Ovigeral spine formula :- $\frac{13\text{-}14}{7} : \frac{11\text{-}12}{8} : \frac{9\text{-}10}{9} : \frac{9\text{-}10}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose (maximum seta length ca 1.0 - 1.5 x maximum scape diameter), subequal in length to chela. Palm constricted at base, widening distally, length ca 0.75 x length of sharply oxeote subequal fingers. Base of immovable finger with tuft of short setae, movable finger non-setose. Dentition uniform on both fingers, needle shaped, separated distally by ca 1.0 - 1.5 x basal width. Immovable 18 - 20. Movable 20 - 22.

Legs. Generally heavily setose. Relative coxal lengths :- $1 \triangleq 3 = 0.5 \times 2$. Coxae sparsely setose. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length, ca 0.8 x tibia 2 length. In male femur of uniform diameter, with 4 - 5 raised ventral cement nodules. In female, femur inflated. Femur sparsely setose in both sexes. Tibia 1 & 2 heavily setose (maximum seta length ca 4.0 - 5.0 x maximum segment diameter).

Tarsus length ca 0.33 x propodus length. Propodus armed with 12 - 16 uniform ventral spines. Terminal claw length ca 0.5 x propodus length. Auxiliary claw length ca 0.5 x terminal claw length.

Graceful morph. (fig 2.23).

Trunk. Three complete intersegmental articulations, sparsely setose. Lateral processes essentially cylindrical, separated by ca 0.75 x their proximal diameter, lacking tubercles, dorsally setose. Neck constricted anteriorly, length subequal to posterior diamter. Centre of ocular tubercle situated at anterior margin of 1st lateral processes, cylindrical with domed crown and two dorso-lateral projections, bearing 4 pigmented eyes. Ovigeral mound touching anterior of 1st lateral process. Abdomen pyriform. Posture horizontal.

Proboscis. Subequal in length to cephalic somite. TYPE B"'.

Palps. 1st - 4th essentially cylindrical, 5th elongate- ovate. Relative segment lengths :- $1 < 4 < 5 < 3 < 2$. Setation, 1st absent, 2nd and 3rd sparse, 4th and 5th heavy uniform (maximum seta length ca 1.5 x maximum segment diamter).

Adult oviger. Relative segment lengths :- $1 \simeq 2 \simeq 3 \simeq 7 \simeq 8 \simeq 9 \simeq 10 < 6 < 4 \simeq 5$. In female, segment 6 length ca 0.66 x length segment 5. In male, segment 6 length ca 0.33 x length segment 5. In male, segment 5 with heavily setose distal bulb.

Ovigeral spine formula :- $\frac{12-13}{7} : \frac{9-10}{8} : \frac{7-9}{9} : \frac{9-10}{10} + S.$

Chelicerae. Scape essentially cylindrical, sparsely setose, subequal in length to chela. Palp constricted at base, widening distally, sparsely setose, length ca 0.66 x length of sharply oxeote subequal fingers. Base of immovable finger with tuft of long setae, movable finger non-setose. Dentition uniform on both fingers,

needle shaped, separated distally by ca 1.0 - 1.5 x basal width. Immovable 11 - 12. Movable 14 - 15.

LEGS. Generally heavily setose. Relative coxal lengths :- 1 ≏ 3 = 0.5 x 2. Coxae with sparsely setose dorsodistal comb over articular membrane. Genital pore ventrodistal on coxa 2 of all legs, not elevated. Femur and tibia 1 subequal in length, ca 0.8 x tibia 2 length. In male, femur of uniform diameter with 2 - 5 raised ventral cement nodules. In female, femur inflated. Femur sparsely setose in both sexes. Both tibiae heavily setose (maximum seta length ca 3.0 x maximum segment diameter). Tarsus length ca 0.5 x propodus length. Propodus and tarsus heavily setose. Propodus armed with 11 - 17 uniform ventral spines. Terminal claw length ca 0.33 x propodus length. Auxiliary claw length ca 0.5 - 0.66 x terminal claw length.

Size ranges. (See tables 2.17 and 2.18).

Distribution.

Eastern Arctic. (Map 2.15). Recorded from Iceland, Faroe Channel, Norway and Spitsbergen. A warm water species. Stephensen (1933) states that few records are from truly Arctic waters. Mean depth range from 200 - 600 metres. Deepest record is 1400 metres from the Faroe Channel.

General. Recorded near Cape Farewell (Greenland) and southwards to the Grand Banks (Hedgpeth, 1963). The most easterly record for this species is from the Central Bank in the Barents Sea.

Remarks. Nymphon tenellum comprises two morphs. The more common is robust and coincides well with the Nymphon spinosum as described by Sars (1891). The other morph is, by contrast, graceful in its general appearance with the spaces between adjacent lateral processes being wider than in the more common form. This morph coincides

well with the description of Nymphon tenellum Sars (1888). Although the two morphs differ significantly, graphs 2.5 and 2.6 show their growth patterns to be similar. The distance separating the lateral processes varies continuously throughout the species from the graceful to the robust form. The correlation coefficients for the two morphs are close enough in both cases to combine the two former species under a single specific epithet. Neither form is common, but the graceful morph is by far the rarer. The largest number of individuals collected during one expedition is seven (G.J. Cranmer. West Spitsbergen, 1978.).

Although the rarer of the two morphs nomenclaturally , the species must be named N.tenellum, as this is the older name , taking precedence over N. spinosissimum, which is reduced to a junior synonym.

Although both morphs share a similar distribution pattern, the graceful one is the more scarce. It has been recorded by Sars (west of Finmark), Norman (Faroe Channel), Hedgpeth (N.E. America) and the author (West Spitsbergen). The records from the Ingolf expedition (Meinert, 1899) are, according to Stephensen (1933), doubtful. He writes " none of them are N.tenellum and can scarcely be determined with certainty." He identified them as probably N.macronyx.

The robust morph (N.spinosissimum Norman, 1894) has, together with most of the other species within the former genus Chaetonymphon, been in some taxonomic disarray for many years.

The first species discovered of this subgroup of Nymphon was N.hirtum Fabricius (1794). Many authors doubt Fabricius' original description and maintain that the first valid description of this species in the literature was given by Krøyer (1844).

In 1842, Goodsir described a similar species, N.spinosum from the northern North Sea. This was followed in 1853 by the discovery of a larger species, N.hirtipes Bell, from Nova Scotia.

Sars, in his epic monologue of 1891, redescribed all three species and

added another, N.tenellum. However, Norman (1894) queried the description of N.spinosum, stating that it differed from Goodsir's original, which bore more resemblance to N.hirtum. He thus synonymized N.spinosum Goodsir with N.hirtum, and renamed N.spinosum Sars, N.spinosissimum, thereby rectifying the nomenclatural problem. N.spinosum being the junior synonym of N.hirtum, the name cannot now be used for another species.

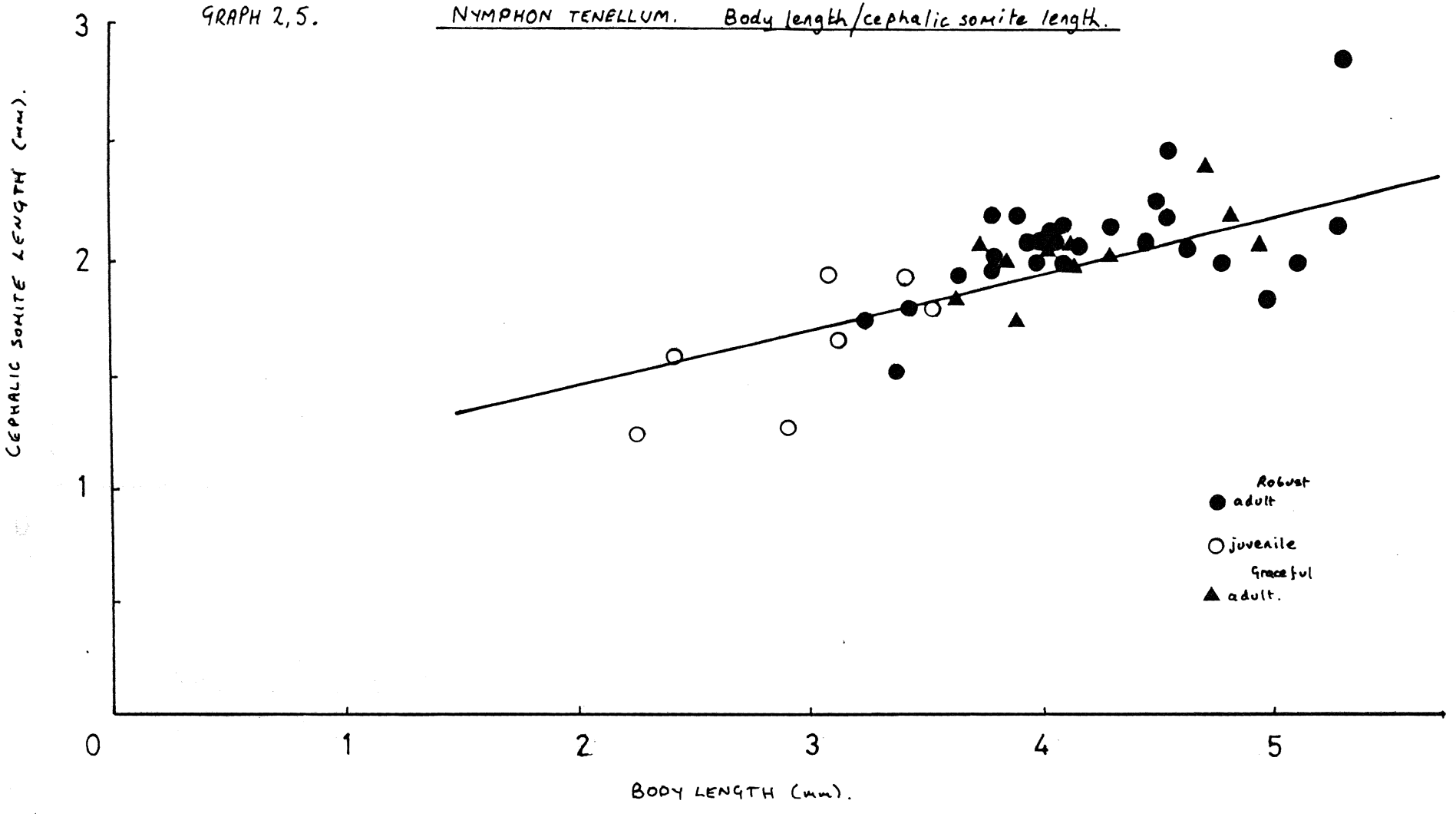
The problem has been complicated further by Meinert (1899) and Mobius (1901), and perpetuated by Schwimkewitsch (1930), Losina-Losinsky (1935, 1961) and Nesis (1960). These authors have synonymized N.hirtipes with with N.spinosissimum to form a composite species N.spinosum Sars. Appellöf (1910, 1916) went even further and included N.hirtum within this epithet, explaining that the separation of N.hirtipes and N.spinosissimum with N.hirtum was doubtful. This is nomenclaturally incorrect. N.hirtum is the senior homonym and cannot be reduced to a junior synonym of a later later name, in this case N.spinosum.

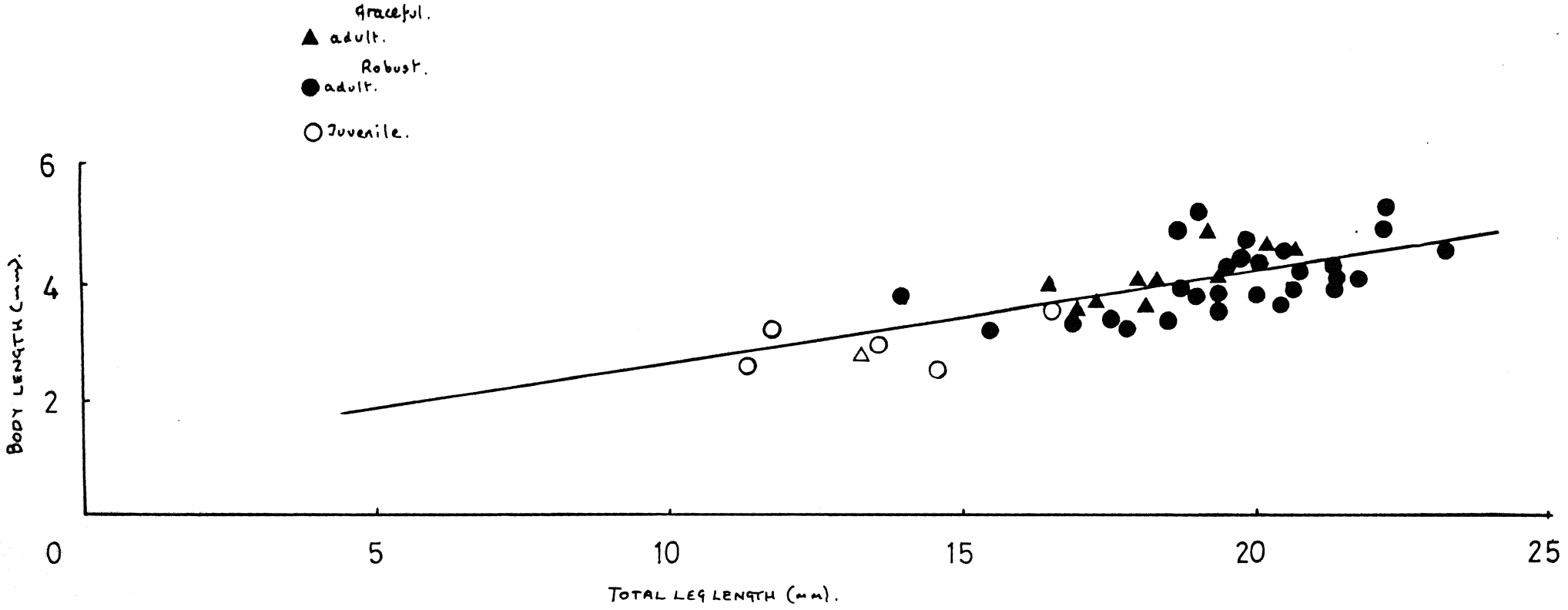
The distribution of N.hirtum is different from N.hirtipes and N.spinosissimum, being generally far more southerly. It also differs in morphology, possessing shorter leg setation and more diminutive chelae than the other two species.

N.hirtipes differs from N.tenellum (including N.spinosissimum) in adult size, being a much larger species. In addition, they differ morphologically, in the relative proportion of the terminal claw length to the auxiliary claw length.

Meinert (1899) himself could hardly agree with his own diagnosis, he writes "of the very large number of specimens I have had the oppotunity of examining, the species (N.spinosum) appears very variable, but I find no sufficient reason to divide the forms hither into two species, even if I acknowledge that most of the specimens found can tolerably well be said to belong either to N.spinosum of Sars (N.spinosissimum Norman), or to his N.hirtipes."

GRAPH 2,5. NYMPHON TENELLUM. Body length/cephalic somite length.





GRAPH 2.6. NYMPHON TENELLUM. Body length / Total leg length.

Table 2.17. Nymphon tenellum (robust morph) size ranges.
(In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	3.68 - 5.20	3.76 - 5.20	2.24 - 3.52
Proboscis	1.68 - 2.24	2.40 - 2.48	1.00 - 1.98
Abdomen	0.40 - 0.88	0.48 - 0.96	0.40 - 0.96
Total palp	2.92 - 3.68	2.92 - 3.92	1.44 - 3.68
Cephalic somite length	2.08 - 2.56	2.32 - 2.48	1.28 - 1.92
Cephalic somite width	1.60 - 2.40	2.00 - 2.64	1.36 - 1.84
Oviger.4	1.48 - 1.86	1.18 - 1.44	
Oviger.5	2.09 - 2.43	1.14 - 1.33	
Oviger.6	0.91 - 1.10	0.76 - 1.10	
Coxa.1	0.72 - 0.88	0.64 - 0.92	0.48 - 0.72
Coxa.2	1.60 - 1.76	1.00 - 1.52	0.88 - 1.00
Coxa.3	0.64 - 0.80	0.56 - 0.92	0.48 - 0.56
Femur	3.28 - 4.48	2.80 - 5.40	2.24 - 3.52
Tibia.1	3.60 - 4.96	2.72 - 5.60	2.48 - 4.40
Tibia.2	4.88 - 6.00	3.76 - 6.80	3.04 - 4.52
Tarsus	0.48 - 0.88	0.48 - 0.72	0.32 - 0.64
Propodus	1.12 - 1.60	0.76 - 1.72	0.88 - 1.28
Terminal claw	0.50 - 0.80	0.64 - 1.04	0.48 - 0.64
Auxiliary claw	0.27 - 0.48	0.27 - 0.52	0.22 - 0.32

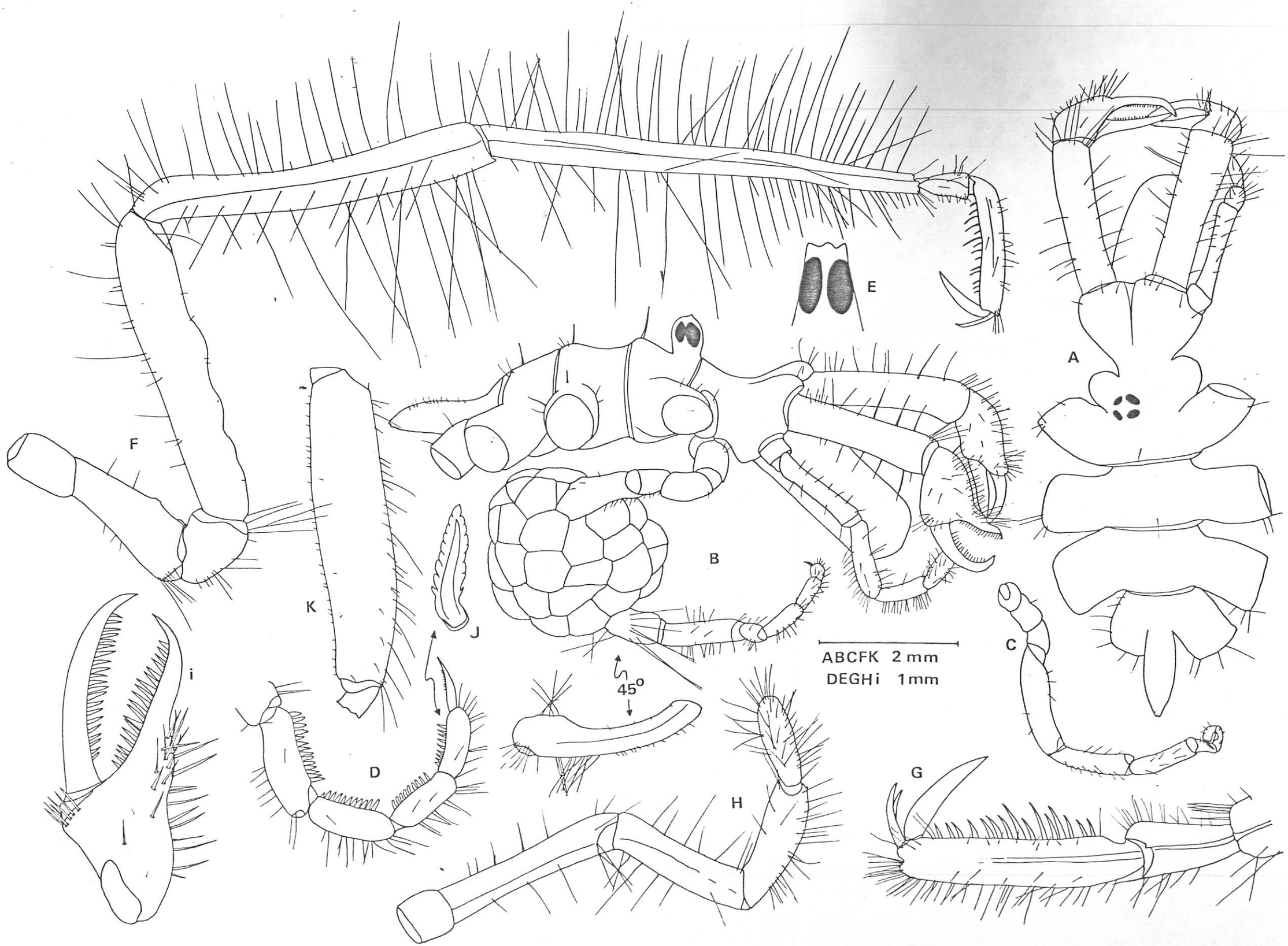
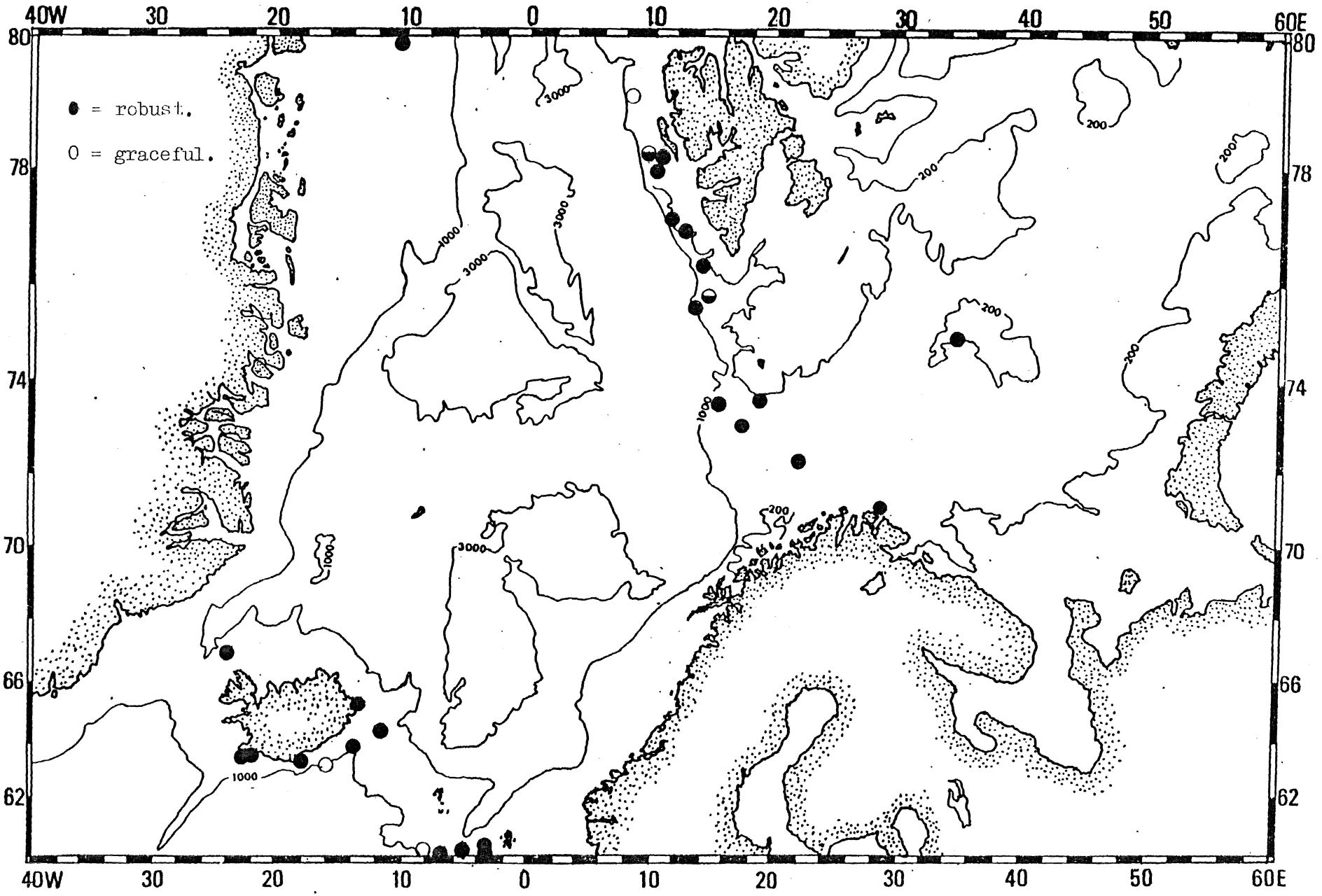

E
A
F
K
J
B
C
i
D
45°
H
G
ABCFK 2 mm
DEGHi 1mm

Table 2.18. Nymphon tenellum (Graceful morph) size ranges. (In millimetres).

	MALE	FEMALE	JUVENILE
Trunk	3.84 - 4.64	3.92	2.88
Proboscis	1.44 - 1.92	1.44	1.28
Abdomen	0.64 - 1.04	0.96	0.44
Total palp	2.68 - 3.46	2.64	1.59
Cephalic somite length	1.76 - 2.40	2.08	1.44
Cephalic somite width	1.68 - 2.16	1.68	1.36
Oviger.4	1.37 - 1.67	1.25	
Oviger.5	1.44 - 1.98	1.32	
Oviger.6	0.76 - 0.87	0.56	
Coxa.1	0.56 - 0.72	0.64	0.40
Coxa.2	1.44 - 1.92	1.44	1.27
Coxa.3	0.56 - 0.80	0.64	0.48
Femur	3.28 - 4.00	3.92	2.72
Tibia.1	3.76 - 4.56	4.16	3.04
Tibia.2	5.02 - 5.76	5.36	3.92
Tarsus	0.64 - 0.72	0.72	0.40
Propodus	1.20 - 1.52	1.20	0.80
Terminal claw	0.42 - 0.56	0.48	0.36
Auxiliary claw	0.32 - 0.40	0.40	0.16

Map 2.15. Nymphon tenellum.



SUMMARY.

Morphological discoveries relating to the Eastern Arctic members of the genus Nymphon have led to a revision of the group and fifteen species are now distinguishable and are here described. It has not proved necessary to propose any new species.

The majority of problems have concerned the species belonging to the former genus Chaetonymphon Sars 1891, which forms one of the two natural subgroups within the arctic pycnogonid fauna.

These species (Nymphon hirtum, N.hirtipes, N.macronyx and N.tenellum) are superficially similar morphologically and this, over the past century, has been the source of much confusion, only N.macronyx having avoided the forray (See Remarks section for N.tenellum). To compound the problems two species have been found to exhibit polymorphism.

The two morphs of Nymphon hirtipes are identical in form and relative proportions but differ in the mean size of the adult. The larger morph is the more numerous, the smaller one occurring in only a few localities on the West Spitsbergen fishing banks. The morphological similarity, coupled with the fact that they have not been found together in any locality, is an indication that the size difference may be the result od environmental influences rather than being of genetic origin.

Nymphon tenellum as described here, however, is a combination of two former species. The more abundant, robust, morph is the former N.spinosissimum Norman, 1908, whilst the rarer, more graceful, morph is N.tenellum Sars 1891. In the Eastern Arctic they are often found together in the same locality, in contrast to the spatial separation of the two morphs of N.hirtipes.

The morphological distinction between the eleven members of the other subgroup are slight, but there is variation within the more abundant species which has led to their fragmentation.

Nymphon grossipes is one of the more abundant species in the region and also the most variable, especially in the lengths of the neck and tarsal segments (tarsus and propodus), however, the shape of the chelae, together with the thick tarsal segments characterizes the species (Hedgpeth, 1948).

A number of authors, including Sars (1891) and Schimkewitsch (1930) have separated N.grossipes into three species - N.grossipes N.mixtum Krøyer 1844 and N.glaciale Liljeborg 1851 . To increase the confusion other authors have added further species, for example, N.piliferum Carpenter 1890.

Stephensen (1936) and Hedgpeth (1948) were both unable to distinguish the separate species from N.grossipes. Hedgpeth stated "that I see no purpose in trying to maintain these forms, either as distinct species or varieties".

The results of the biometric analyses of N.grossipes, N.mixtum N.glaciale and N.piliferum comfirm the conclusions of Stephensen and Hedgpeth. The various species cannot be distinguished and although N.grossipes is a highly variable species the extent of this variability is not sufficient to warrent the fragmentation of the species.

3. MORPHOLOGY OF THE TERMINAL LEG SEGMENTS.

A great deal of research in recent years has concerned the functional morphology of arthropod locomotion, but very little has been devoted to the Pycnogonida.

Locomotion amongst pycnogonids may be by means of walking or swimming (Cole, 1901; Prell, 1910; Morgan, 1971; 1972 & 1978) and several species, such as Nymphonella tapetis Ohshima, 1927, are known to be able to burrow in sand (Arita, 1937).

Schram and Hedgpeth (1978) have analysed the walking movements of the large eight, ten and twelve legged antarctic species, observing them to walk with a somewhat arhythmic striding movement with the ten and twelve legged forms appearing to be better coordinated than those with only eight. They have also observed that other species, especially intertidal forms, stumble along with apparently uncoordinated movements until they find something to cling to. Once clinging, they remain stationary for long periods of time.

Both of these patterns occur in the genus Nymphon and personal observations together with biometric analysis of the terminal leg segments show that the Eastern Arctic species of the genus can be divided into two groups with respect to their leg morphology.

The first is exemplified by the graceful species Nymphon elegans, N.strömi, N.longitarse, N.longimanum, N.leptocheles and N.macrum. The total leg length in all of these species is between four and five times the body length, with the tarsus and propodus being approximately equal in length. Both segments are long, straight and uniform in diameter. The ventral propodal spination consists of

numerous, short uniform spines, which superficially resemble setae. The terminal claw is long, straight and thin and, in most species, the auxiliary claws are reduced to less than one-third the length of the terminal claw. Nymphon macrum is the exception, having well developed auxiliary claws which are over half the length of the terminal claw. (Figs 3.1a & b).

The second group consists of the remaining nine species, all of which exhibit some modification of the terminal segments of the walking leg and propodal spination which enables them to cling to filamentous organisms such as hydroids.

Two species within this group (Nymphon macronyx and N.sluiteri) have the graceful morphology of the first group, but differ from them in the morphology of the terminal leg segments. The tarsus is shorter than the propodus, which bears more strongly developed uniform ventral spines. The terminal claw is exceptionally long, being subequal to the propodus, and straight along its inner edge. The auxiliary claws are markedly reduced. The terminal claw is highly manoeuverable and can be folded over the ventral propodal spination to form a clinging appendage. (Fig 3.2a).

The remaining seven species of the group show greater modification of the terminal leg segments and it is possible that this makes them better adapted for clinging.

In four of these (Nymphon grossipes, N.megalops, N.microrhynchum and N.serratum) the tarsus is approximately equal to, but never less than, the length of the propodus, which bears only a few strongly developed ventral spines. The spines have a maximum length equivalent to half the maximum limb segment diameter. The longest spines are usually on the mid portion of the segment, where

they are opposed to the distal end of the stout arcuate terminal claw (Fig 3.2b).

The last three species of this group (Nymphon hirtipes, N.hirtum and N.tenellum) are all comparatively robust in their morphology, having a leg length of approximately three times that of the body length. The shape of the propodus and the arrangement of the terminal armature (spination and claws) are similar to those of the previous four species. However, in addition the tarsus is reduced, being less than half the length of the propodus. This modification allows greater manoeuverability of the terminal leg segments thus enabling the animals to maintain a secure hold (Fig 3.3a & b).

Pycnogonids are not the only group of marine animals in which appendages are used for clinging. Within the Caprellidae, a common group of marine amphipod, the terminal segments of the second and third thoracic appendages, the gnathopods are modified in a similar manner to that shown by the clinging species of pycnogonids (Fig 3.4b). This adaptation enables caprellids to cling effectively to filamentous organisms such as hydroids and bryozoans, where they are most commonly found.

These variations in the leg morphology of Nymphon may represent a possible evolutionary sequence between the two morphs and thus indicate the monophyletic origin of the habit within the genus. From the evidence available it is impossible to judge which of the two morphs is the primitive condition. The extinct pycnogonid Paleoisopus problematicus Brolli, 1928, from the Hunsrück shale, has been found embedded, clinging to the stalked hydroid Imitatocrinus gracilior (Bergström et al., 1980). However, amongst extant pycnogonids the striding morphology could be held

to represent the primitive condition since it is a characteristic of the colossendeids, a group which also lacks the ovigeral egg nursing habit and has comparatively simple gonad and cement gland morphology.

There is also insufficient evidence to show how many times such an adaptation may have evolved within Nymphon , as the genus includes a number of morphological adaptations towards the clinging habit.

If the long-legged morph is taken to be the more primitive then species such as N.strömi and N.longitarse representthe first stage of the evolutionary sequence, having comparatively unmodified terminal leg segments which are best suited to a striding habit.

The second stage is represented by two species, N.macronyx and N.sluiteri. Both have the basic gracile morphology characteristic of the striding forms, their only modification towards the clinging habit being the exceptional length of their terminal claws.

N. grossipes and similar species are all representitives of the third stage which, although retaining the graceful morphology, have terminal leg segments showing greater modification towards clinging, with the terminal armature all being well developed.

In the final stage (N.hirtipes) the terminal armature is similar to that of the last group but, in addition, the general body form is more robust with a reduction in the length of the tarsus.

The morphometric analytical studies undertaken consist of a series of multivariate analyses of the ten most common Eastern Arctic Nymphon species. The relationship of the total leg length to body length (Graph 3.1) shows that the majority of the species

are strikingly similar. These are the species which either belong to the striding group or which cling and yet retain a graceful striding morphology, even though their terminal leg segments are modified towards the clinging habit. The two species (N.hirtipes and N.tenellum) which are separated from the main cluster are those with the more robust morphology which is more characteristic of the highly modified clinging species.

The clustering effect is not evident when tarsus length is plotted against propodus length (Graph 3.2). Instead the regression lines are spread more evenly between the typical striding species N.longitarse, which as its name suggests has a tarsus which is longer than the propodus, and the highly modified clinging species N.hirtipes. Lying between these two are others which show characteristics intermediate between clinging and striding morphology.

The graph therefore indicates that the change from a striding to a clinging habit is associated with a reduction in the length of the tarsus relative to that of the propodus.

The presence of well developed auxiliary claws must be an advantage, since they act as hooks with which to secure a hold on filamentous organisms, with the result that the clinging mechanism of the terminal armature can be more effectively used.

Only one striding species, N.macrum, exhibits well developed auxiliary claws. This may be adevelopment which facilitates striding, giving a three-point tip-toe gait, or it could be an early stage in the development of the clinging habit.

The two morphs of Nymphon can be found in other Eastern Arctic

pycnogonid genera, but wheras Nymphon is dimorphic, having both striding and clinging forms, other genera are monomorphic. i.e. there is only one form within each genus.

The Eastern Arctic pycnogonid fauna can be classified into three groups with respect to the morphology of the terminal leg segments and therefore to habit. Two of the types have already been discussed, both of which belong to the genus Nymphon. The third is the squat robust form which is exhibited by the genus Pycnogonum.

1. The striding species. Usually graceful and capable of both walking and swimming. The terminal leg segments remain essentially unmodified with the tarsus and propodus being approximately equal in length. The propodus bears numerous, short weak uniform ventral spines. The terminal claw is long, thin and straight with the auxiliary claws being either reduced or absent. Examples include the genus Colossendeis and some Nymphon species, such as N.strömi and N.longitarse.

2. The gripping species. These are robust and squat with short, powerful and somewhat prehensile legs, capable of walking with difficulty but not of swimming. The tarsus is half the length of the propodus, which lacks ventral spination. The terminal claw is powerful, and the auxiliary claws absent. The only examples of this group are the members of the genus Pycnogonum.

3. The clinging species. More robust morphology than the striding species, all are capable of walking easily but only a few can swim. Characteristically the tarsus is short, being approximately half the length of the stout propodus which bears well developed ventral spination and forms a lock with the stout arcuate terminal claw. Auxiliary claws, when present, may be either well developed

or reduced; this feature usually distinguishes the genus. Examples include Anoplodactylus, Ammothea, Achelia, Phoxichilidium, Pallene, Pseudopallene and such Nymphon species as N.hirtipes and N.tenellum.

Although this classification has been restricted solely to the genera present within the Eastern Arctic, study of reports from other areas of the world would tend to suggest that all pycnogonid genera can be classified in this fashion. This, however, lies outside the scope of the present study.

In Anoplodactylus (Fig 3.4a) the clinging modification appears to have attained its maximum development. The tarsus is short, being less than one-quarter the length of the propodus; the proximal region of the propodus is raised on the ventral surface to form a sole; the ventral propodal spination is dimorphic, the spines of the sole being long and powerful, forming a locking mechanism with the stout arcuate terminal claw, whilst the distal or heel spination is short and uniform, serving to increase the efficiency of the clinging grip. In this genus the auxiliary claws are vestigial.

Schram and Hedgpeth (1978) have conducted one of the few comparative studies of pycnogonid musculature. They report that there are two basic morphological patterns present among antarctic pycnogonids. One is a long-legged variety, represented by the genus Colossendeis, whilst the other variety is squat, with short powerful legs, this being represented by the genus Pycnogonum. Dissection revealed that the musculature of the two varieties differed and that the difference was in the shape rather than the arrangement. When comparing the promotor / remotor muscles

of the Coxa 1 / Coxa 2 joint, they found that the colossendeids have three strips, each arranged in the form of a chevron whereas Pycnogonum has only a single short muscle strip which lacks the chevron arrangement.

The morphology of Pycnogonum comprises sedentary benthic species which move seldom and slowly, even when removed from their food source. They feed epizoically on sea-anemones and other soft bodied invertebrates, the primary function of the legs being to act as clamps, allowing the animal to grasp by sinking the terminal claws into the integument of the 'host'.

Pycnogonum is thought to be a very old form among pycnogonids (J.W.Hedgpeth, personal communication) and has a similar morphology to the cyamids - the external parasites of whales which Linnaeus originally thought of as pycnogonids.

Although the structure of Colossendeis and other striding forms is very efficient for walking and swimming, they too may move little under their own power. Deep sea photographs, such as those produced by Monod (1954), have shown that colossendeids adopt a stationary position, standing with only the tips of their terminal claws touching the substratum, in tip-toe fashion. In addition, laboratory observations of colossendeids have shown that this position is maintained for long periods of time.

Schram and Hedgpeth (1978) think that this may be evidence that the graceful morphology of the striding forms may facilitate their dispersal by bottom flowing currents.

The clinging and striding forms must be more closely related to each other than to the gripping form as both occur within the genus

Nymphon and the gripping form does not. It therefore follows that the musculature of the clinging forms can be expected to resemble that of the striding forms more closely than that of a gripping form such as Pycnogonum. The pattern of the musculature represents the solution to a mechanical problem.

A comparative investigation of the musculature of the three varieties, with special reference to the terminal segments of the walking legs would make an invaluble study. Not only would it shed light on the comparative functional morphology of pycnogonids but it would also facilitate any further consideration of evolution within the group.

GRAPH 3.1.

BODY LENGTH / TOTAL LEG LENGTH.

a. Nymphon hirtipes.

b. Nymphon tenellum.

c. Nymphon grossipes.

d. Nymphon macronyx.

e. Nymphon sluiteri.

f. Nymphon strömi.

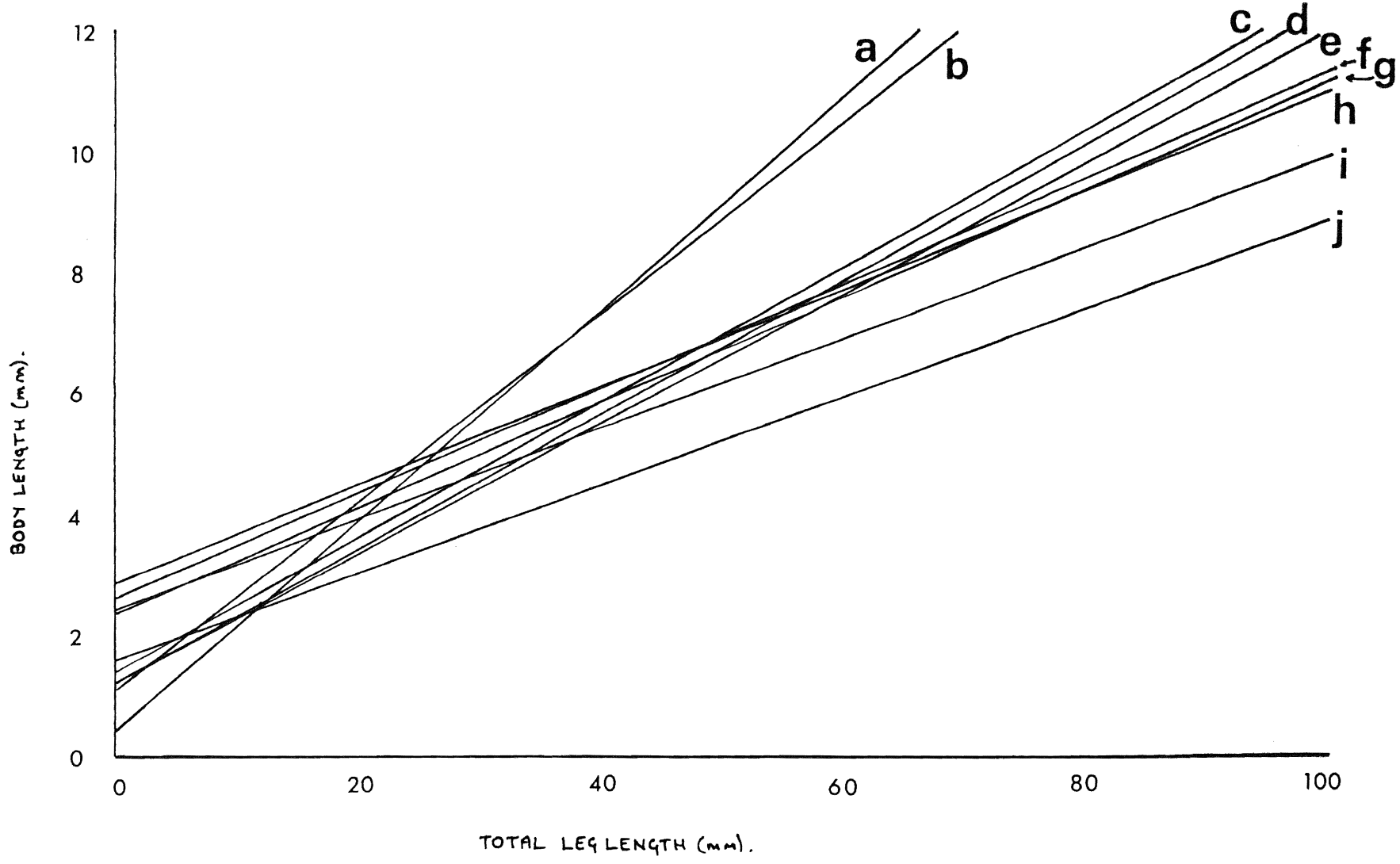
g. Nymphon megalops.

h. Nymphon serratum.

i. Nymphon elegans.

j. Nymphon longitarse.

GRAPH 3.1. SPECIES VARIATION IN BODY LENGTH TO TOTAL LEG LENGTH.



GRAPH 3.2.

TARSUS LENGTH / PROPODUS LENGTH

a. Nymphon hirtipes.

b. Nymphon macronyx.

c. Nymphon tenellum.

d. Nymphon megalops.

e. Nymphon elegans.

f. Nymphon serratum.

g. Nymphon grossipes.

h. Nymphon strömi.

i. Nymphon sluiteri.

j. Nymphon longitarse.

GRAPH 3.2. SPECIES VARIATION IN PROPODUS LENGTH TO TARSUS LENGTH.

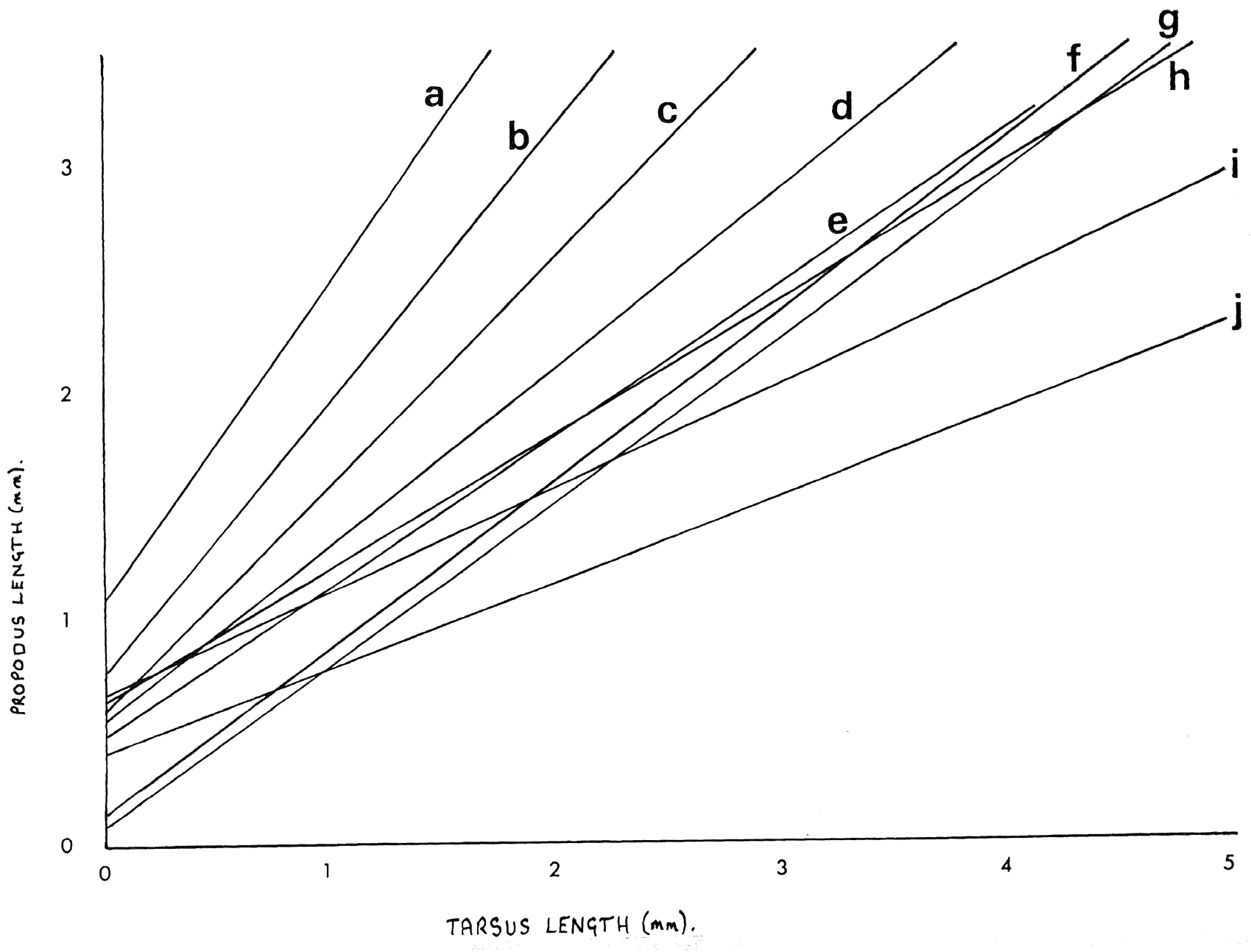


FIGURE 3.1.

MODIFICATIONS OF THE TERMINAL SEGMENTS OF THE LEG TO SUIT THE STRIDING HABIT.

a. *Nymphon elegans* (x50).

b. *Nymphon longimanum* (x50).

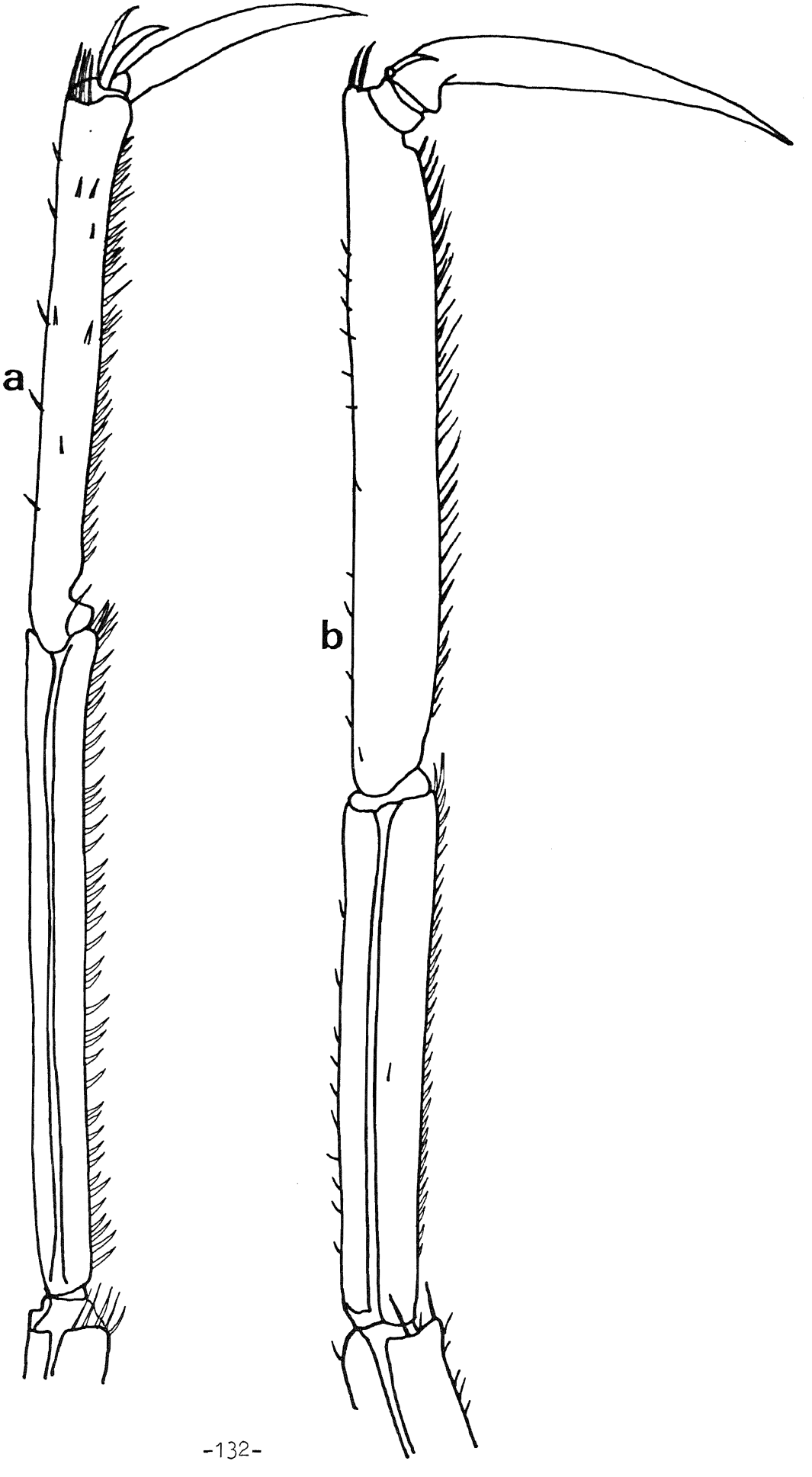

a
b

FIGURE 3.2.

MODIFICATIONS OF THE TERMINAL SEGMENTS OF THE LEG TO SUIT THE CLINGING HABIT.

a. *Nymphon macronyx* (x50).

b. *Nymphon serratum*. (x50).

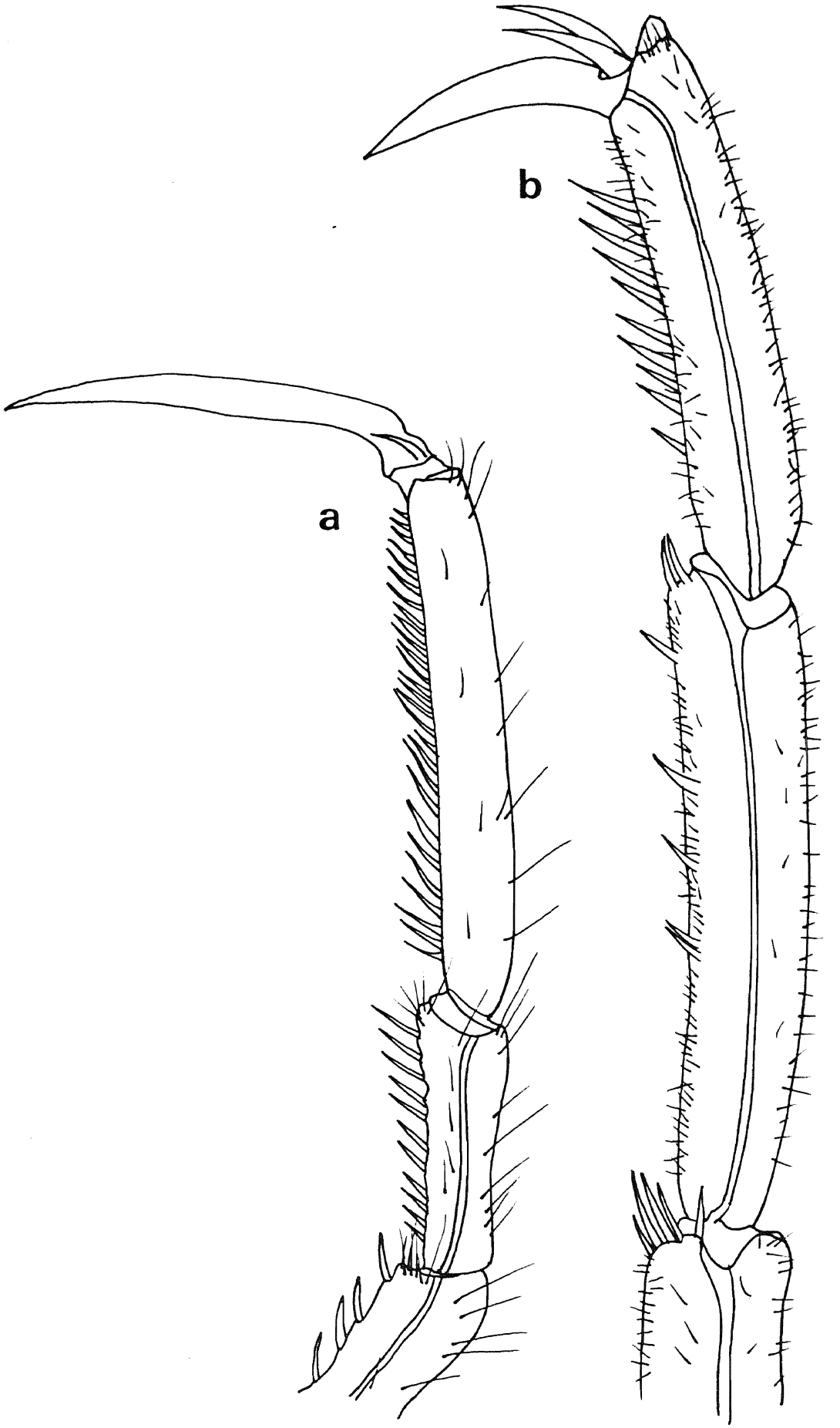

b
a

FIGURE 3.3.

MODIFICATIONS OF THE TERMINAL SEGMENTS OF THE LEG TO SUIT THE CLINGING HABIT.

a. *Nymphon hirtum* (x50).

b. *Nymphon tenellum* (x50).

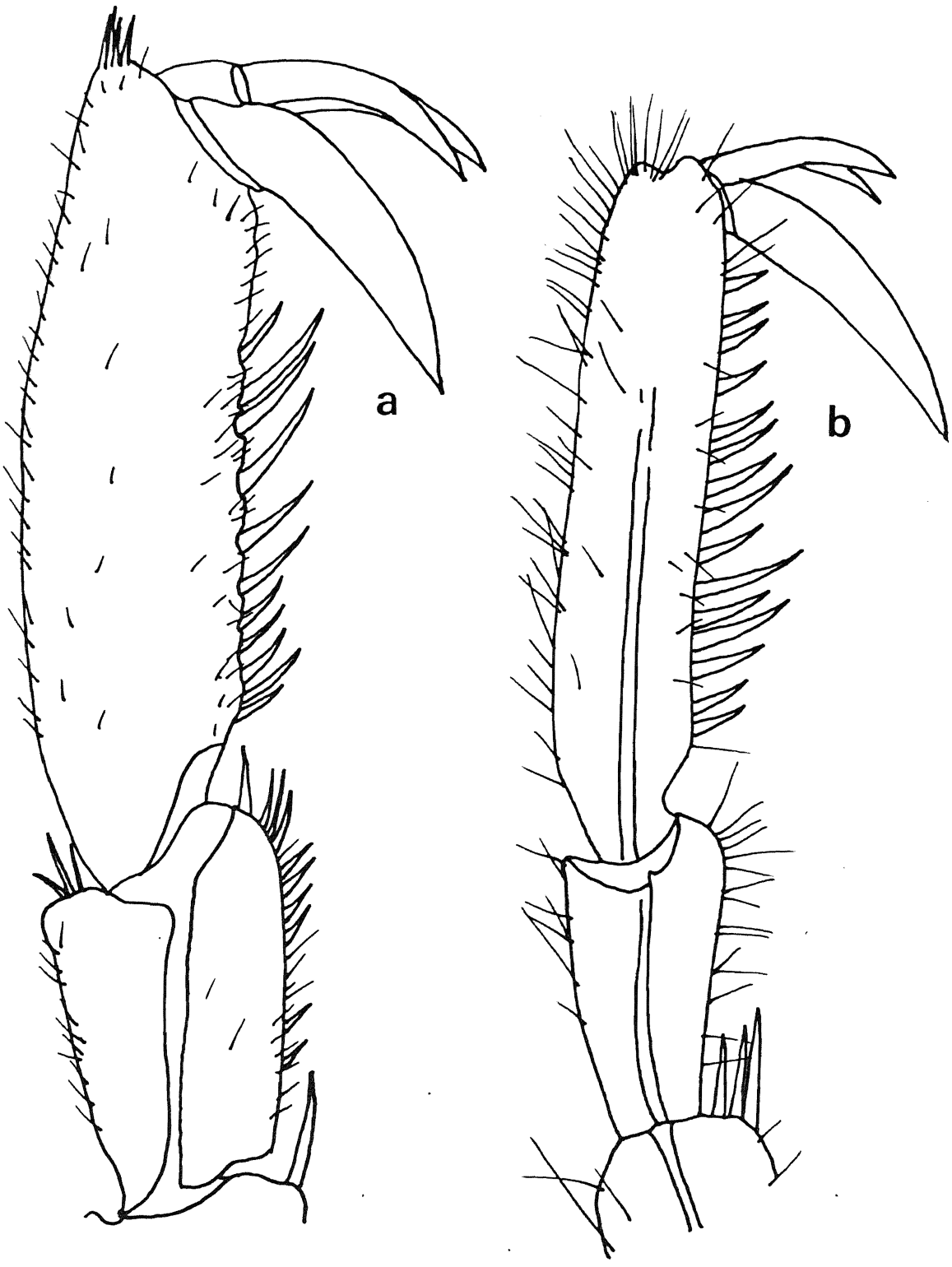

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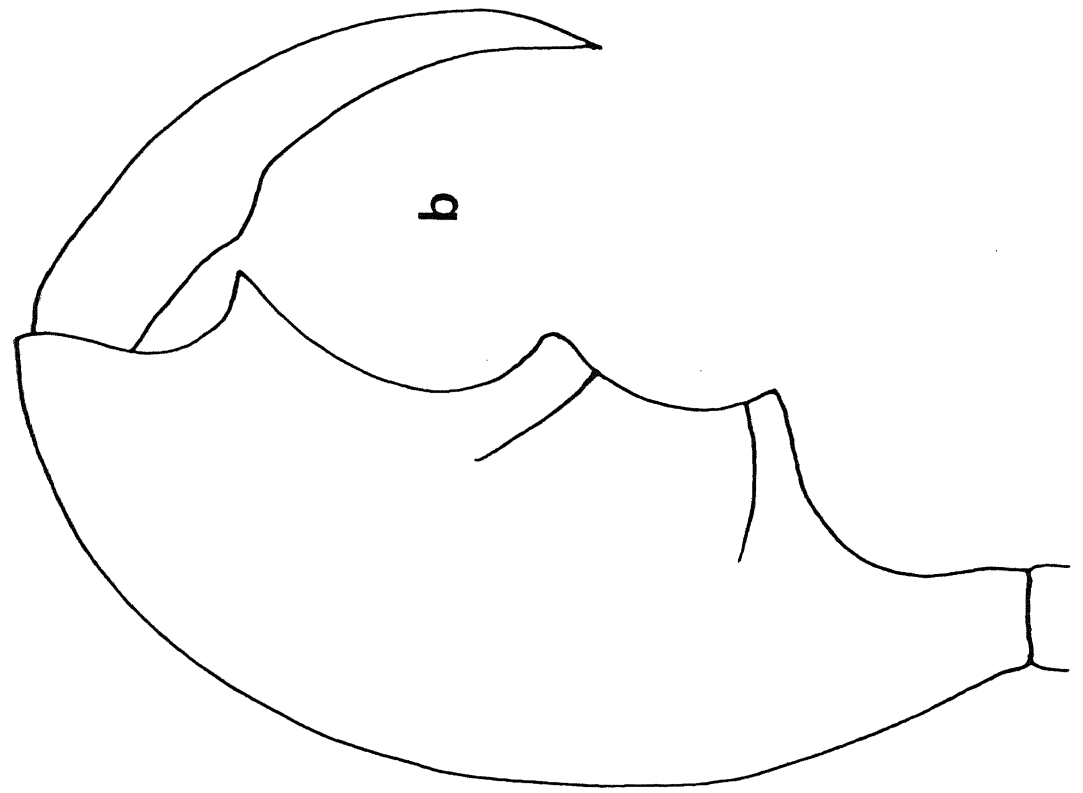
FIGURE 3.4.

a. Anoplodactylus terminal leg segments showing dimorphic propodal spination.

b. Gnathopod of a caprellid, modified to suit a clinging habit.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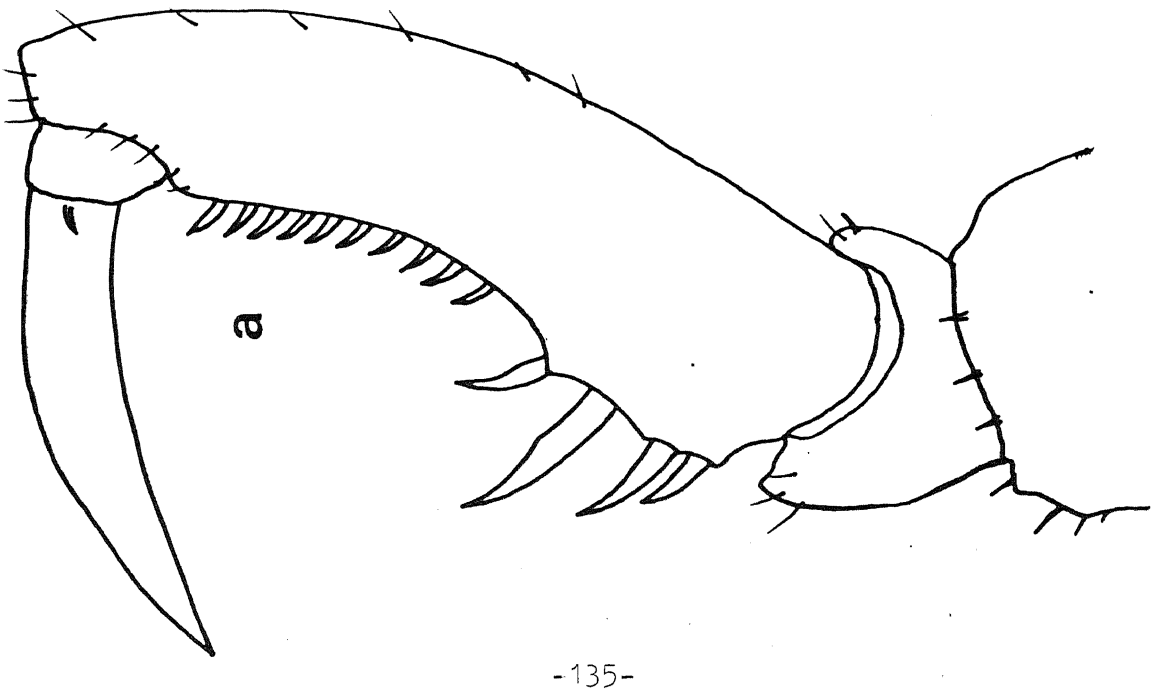

a

4. REPRODUCTION.

With one exception, pycnogonids are dioecious. Marcus (1952) described the single hermaphroditic species, Ascorhynchus corderci, from shallow waters of the Brazilian coast. Specimens were found bearing ovigeral egg masses and having both ovaries and testes in the femora of all walking legs. The hermaphrodite characters of the species were confirmed by Stock (1965) on the discovery of further specimens from the same area. Additionally, gynandromorphs also have been reported within two genera of pycnogonids, Ascorhynchus (Losina-Losinsky, 1974) and Anoplodactylus (Child, 1978). These are abnormal specimens of mixed sex, which are not hermaphrodite, having some tissue genetically and structurally female and other genetically and structurally male.

In all pycnogonids the gonads are in the trunk, lying dorsad to the gut on either side of the heart. Like the digestive system, each gonad sends lateral branches into the walking legs, reaching to the ends of the tibial segments in some species, notably within Colossendeis (Hoek, 1881). In many species the femora of the female are often inflated to accommodate the developing ova. A unique feature of pycnogonids is the presence of multiple genital openings. These are situated on the second coxal segment of some or all of the legs. In Nymphon they occur ventrodistally on all the legs.

Hoek (1881) first described oögenesis in pycnogonids, distinguishing between previtellogenic ova and those containing yolk, and commenting also on the different stages of egg maturation within the ovary. In recent years, the early development of the ova has been studied in detail for European coastal species (Sanchez, 1959; Jarvis & King, 1972; 1975; 1978) the yolk being synthesized within the enlarging ova with only a small extra-oöcytic contribution.

The pattern is similar to that shown in other aquatic chelicerates, such as Limulus, and is considered to be primitive within the Arthropoda.

The number of eggs maturing within a femur at any one time appears to vary between genera. Sanchez (1959) reports that all eggs matured together in a femur of Endeis spinosa, whilst for Callipallene species (Sanchez, 1959) and Propallene longiceps (Nakamura and Sekiguchi, 1980), only two eggs matured at one time.

Little study has been made of pycnogonid spermatogenesis. The sperm are non-motile and study of their ultrastructure (Van Deurs, 1974a & b; King and El Hawawi, 1978) reveals an arrangement of microtubules of the flagellum in 8 - 12 doublets, without a central element. The variation represented by the reduction of the microtubles indicates an evolutionary trend towards the reduction of movement, until, as in Pycnogonum, there are only isolated microtubules without any other organelles.

The primitive arthropodan type of vitellogenesis coupled with what is known of spermatogenesis, further supports the view that pycnogonids may be an early offshoot from the basic arachnid stock.

In those pycnogonids where mating has been observed (Hoek,1881; Cole,1901; Sanchez,1959; King, 1978; Nakamura and Sekiguchi,1980) the male clings to the ventral surface of the female so that the genital pores of each sex are closely aligned. The duration of this pseudocopulation varies between species, taking, according to Cole (1901),only five minutes in Anoplodactylus lentus, whereas Jarvis and King (1972) have reported Pycnogonum littorale taking as long as five weeks! An intermediate duration, however, for the complete process of "copulation" and oviposition is of the order of a few hours, as reported for Nymphon gracile (King and Jarvis,1972) and for

Propallene longiceps (Nakamura and Sekiguchi, 1980).

As the eggs are released they are fertilized and collected into masses. The male of Nymphon gracile performs this task with the ovigerous legs, forming the eggs into ball shaped masses (Jarvis and King, 1970). However, for Propallene longiceps it is the female who collects the eggs with her cvigers before transferring them to the male (Nakamura and Sekiguchi, 1980). In species with reduced ovigers, such as Pycnogonum littorale, the eggs are not cemented together in balls, but are instead attached in a flattened mass to the ventral side of the male's trunk. The Colossendeidae are an exception; although both sexes possess well developed ovigers, no specimen of either sex has ever been found carrying maturing egg masses, and their development remains a total mystery. Amongst the genera that do collect their egg masses, the eggs are cemented together using a silk-like adhesive produced from glands situated on the ventral surface of the male femora.

Cavanna (1876) first demonstrated that it was the male and not, as previously thought, the female, that receives the eggs after fertilization (see Hoek, 1881). There are, however, exceptions to this in the literature. Hoek (1881) reports finding a female of Nymphon brevicaudatum carrying maturing eggs, and Gordon (1932) reports a female Nymphon with eggs on the femora of all legs. However, neither author states specifically whether these were pycnogonid eggs. Hedgpeth (1964) has found prosobranch mollusc eggs attached to the femora and tibia of the Antarctic pycnogonid Colossendeis megalonyx, and within the Arctic it is not uncommon to find mollusc eggs attached to the legs and bodies of pycnogonids, especially the colossendeids and larger Nymphon species (personal observation).

The vast majority of pycnogonid species develop via a larval phase, the protonymphon (fig 4.1). A few species, such as

Boreonymphon robustum, develop directly into juveniles from large yolky eggs (Fage, 1954). Some species, such as Propallene longiceps, hatch out as post larvae, with three or four pairs of appendages, but in Nymphon the young hatch out as protonymphon larvae, with three pairs of appendages - chelicerae, palps and ovigers. The protonymphon larva is oval in shape and superficially resembles the nauplius larva of barnacles, except that it cannot swim. Further somites and appendages are added posteriorly as the larva develops into an adult.

Nakamura (1981) reports that Propallene longiceps undergoes nine moults from hatching to adult. The first moult occurs at the time of hatching, so that the hatched larva is already a second instar larva. Nakamura states that " it seems to be general that pycnogonid larvae pass through about nine moults from hatching to adult". Adults, however, may grow by a process not involving moulting (King, 1973).

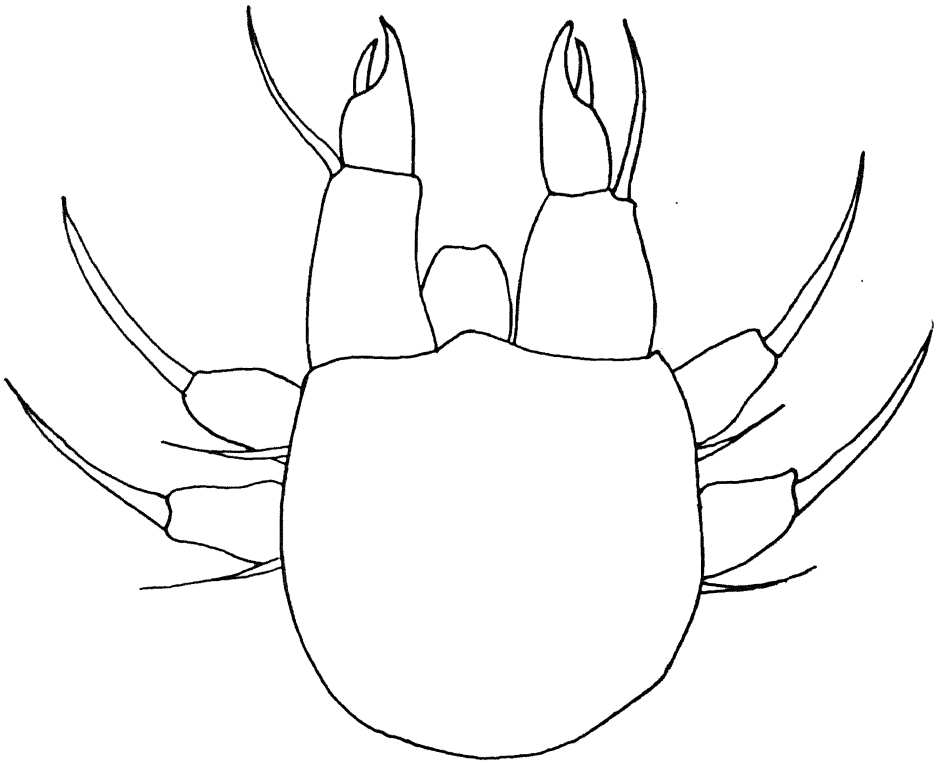
In Nymphon, when the larvae hatch they remain attached to the male ovigers, hanging by threads of silk. The larvae of the majority of Eastern Arctic Nymphon species are lost from the male soon after hatching. However, in a few species (N.hirtipes (Hedgpeth, 1963), N.sluiteri (Hedgpeth, 1963; Just, 1972) and N.grossipes (personal observation)) the larvae remain attached to the male oviger for a much longer period. They are lost from the male only when metamorphosis is nearly complete - with only the posterior pair of legs remaining as buds (fig 4.2). In laboratory conditions, the larvae of N.hirtipes were found to die soon after leaving the male, without developing beyond this sub-adult phase. This lends support to the view that a further stage, as yet unknown, may intervene in the life cycle of this species, perhaps involving a parasitic phase (P.R.Richards, personal communication).

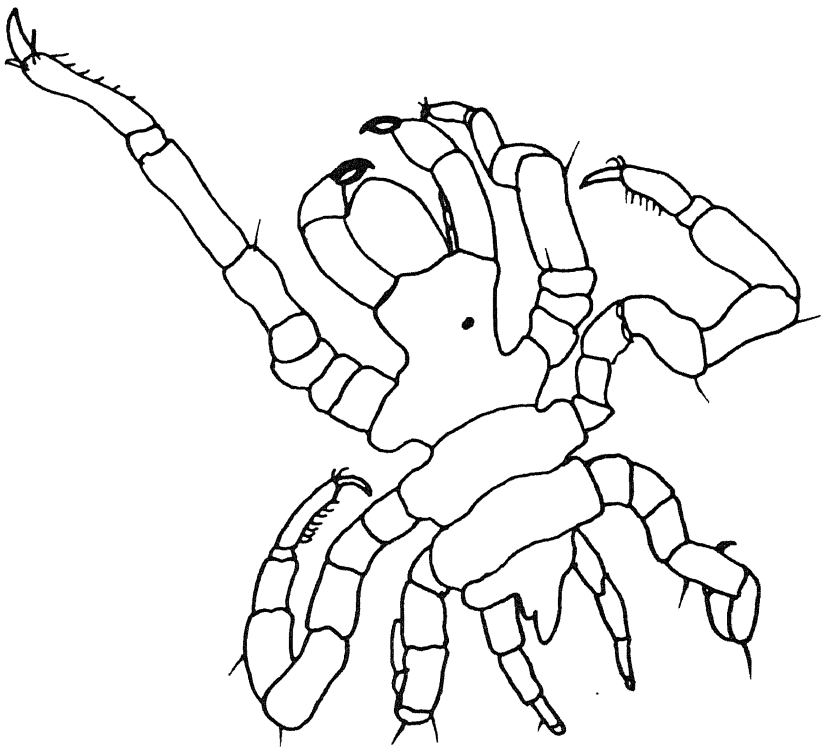
FIGURE 4.1.

Nymphon hirtipes Protonymphon larva (x 100).

FIGURE 4.2.

Nymphon hirtipes Sub-adult stage.





In other genera, in other areas, larval sites of development have been recorded for pycnogonids. These include a number of species whose larvae encyst as galls within polyps of hydroids, where their metamorphosis is usually completed. The species of hydroid parasitized by the larvae is usually one on which the adult is known to feed. The larvae of Anoplodactylus petiolatus have been found encysting within the hydroids Campanularia flexuosa (Dogiel,1911) and Hydractinia echinata (Giltay, 1928). The larva of Nymphonella tapetis completes its development within the mantle cavity of the bivalve Paphia phillippinarum, feeding parasitically and undergoing metamorphosis before leaving to continue a free living adult life. A similar situation has been observed in Achelia chelata on the Californian coast, which is a parasite of Mytilus californianus in winter and spring, but leaves the host in summer (J.W.Hedgpeth, personal communication).

Within the Eastern Arctic, the life cycle of only one pycnogonid, Boreonymphon robustum, is completely known. The eggs develop directly into juveniles, which are not lost from the male, but remain attached, clinging to the body, ovigers and walking legs, and not leaving until they are over one-third the size of the parent (Hedgpeth, 1963; Just, 1972).

Breeding seasons amongst pycnogonids have been little studied. Jarvis and King (1978) report that shallow water British species are little different from most other temperate shallow water invertebrates in having a prolonged breeding season, lasting often for most of the year. According to Gordon (1932) the breeding season of subantarctic pycnogonids is from May to July and, for Antarctic species, from October to April: the greater part of the austral summer. This is atypical for polar marine invertebrates, whose breeding season is usually strictly limited, and closely

synchronized with the plankton blooms of late spring and early summer.

Records of sex ratios among pycnogonid species are very sparse, indeed, only one comment has come to light. Giltay (1928) records Pycnogonum littorale along the Belgian coast as having equal numbers of males and females.

4.1 OVIGERS.

Within the Arthropoda, ovigerous legs or ovigers are peculiar to the Pycnogonida. They appear as modified walking legs, arising from lateroventral outgrowths of the cephalic somite, immediately posterior to the palps.

The ovigers are present in both sexes of five of the eight families of Pycnogonida (Hedgpeth, 1947). However, amongst the Phoxichilidiidae Sars (1891), Endeidae Norman (1908) and Pycnogonidae Wilson (1878) they are present only within the males, although Pycnogonum anovigerum Clarke (1956) lacks ovigers in both sexes.

Oviger segment numbers vary according to family, from five within the Phoxichilidiidae, to a maximum development of ten within the Nymphonidae Wilson (1878), Tanystylidae Schimkewitsch (1913) and Colossendidae Hoek (1881).

The function of the ovigers within the females of many small intertidal species is unknown. However, in the large Antarctic and deep sea species the ovigers serve, in both sexes, as cleaning appendages, the terminal ovigeral segments or 'shepherds crook' either being hooked around a leg and combed along the segments, or opened and combed across the body. The denticulate spines along the inner edge of the terminal segments acts as a brush to remove epizoites and detritus which readily become attached to these slow moving animals. In species where cleaning has been observed, for example in the colossendeids, there is no morphological difference between the ovigers of the two sexes.

The second function of the ovigers, which occurs in the males only, is the carriage of the maturing egg masses (Cavanna, 1876). This has been observed in six of the eight families. King (1973) reports that when a male is in possession of egg masses the

cleaning function is suspended, with the result that the animal may become overgrown with epizoites. In the Pycnogonidae, the male ovigers are too reduced to perform this function, the eggs being attached instead, in a flat mass, to the ventral surface of the trunk. In the family Colossendidae, since the males have never been observed to carry egg masses, cleaning appears to be the only function of the ovigers in this group. In addition, however, Nakamura and Sekiguchi (1980) report that the terminal segments of the male oviger in Propallene longiceps are employed in transferring the fertilized eggs from the female oviger to the fourth and fifth segments of the male oviger immediately after mating.

Within the genus Nymphon, the ovigers are of ten segments. The proximal three correspond to the coxae of the walking legs, being short. The three central segments, which are equivalent to the femur and tibiae, are the longest. The four short distal segments, each of which bears on its inner edge a row of leaf-like denticulate spines, form a structure similar to a shepherd's crook (Fig 4.1.1). In Nymphon, the tenth segment bears a distal, serrated, terminal spine.

Amongst species in which both sexes have ovigers, those of the male are almost always longer than those of the female. This is especially so within the Nymphonidae and Colossendidae. In Nymphon, this increase in male ovigeral length, together with other morphological adaptations such as swellings, serrations and setae, is most pronounced on the fourth, fifth and sixth segments; these are the main areas of egg mass attachment.

All fifteen species of the genus Nymphon within the Eastern Arctic area exhibit sexual dimorphism in the structure of the oviger, particularly in length. This dimorphism varies from species

to species, but all the variations fall easily into five distinct groups based on the morphology of the ovigers of the males (table 4.1.1).

I. The fifth segment only is modified in the male, showing an increase in length by as much as 70% compared with that of the female. In addition, there is a slight narrowing in the diameter of the segment compared with that of the female, for example, Nymphon hirtum, N.megalops and N.serratum, (fig 4.1.2a & b).

II. The whole oviger is increased in size compared with that of the female. However, the increase is directly proportional to the dimensions of the female oviger, thus making sex-identification on this basis very difficult. This is especially so within the smaller adult size-ranges where the gonads are not easily detectable, as in Nymphon longimanum and N.strömi, (figs 4.1.3a & b).

III. Only the fourth and fifth segments show an increase in length, this often being marked. The fifth segment, especially, is very long and thin, being either straight as in Nymphon elegans and N.longitarse, or curved as in N.macronyx and N.macrum. The pattern is characteristic of the more graceful forms, (figs 4.1.4a & b).

IV. Similar in general structure to III, but the fifth segment is distinctly swollen distally to accommodate the muscle attachments and the insertion of the sixth segment. Although this is an adaptation of graceful forms, the members of this group are usually more robust in general appearence than those of III, as in Nymphon grossipes, N.microrhynchum and N.sluiteri, (figs 4.1.5a & b).

V. Both fourth and fifth segments are longer in the male and possess additional modifications which increase the surface area of the appendage. Nymphon leptocheles has a series of rounded nodules on the inner edge of the fifth segment, and the sixth segment has a series of serrations in the same plane, (figs 4.1.6a & b). In the

robust species N.hirtipes and N.tenellum there are both median and distal swellings on the fifth segment, both being heavily setose, (figs 4.1.7a & b).

GLANDS.

Within the Eastern Arctic, both sexes of the Nymphon species present have a gland-like structure on the ovigers. This is situated near the proximal end of the fourth segment, on the outer face.

In the majority of species the structure is minute and can be located only with the aid of a microscope. In Nymphon megalops and N.serratum, however, the structure appears as a prominent mound or nodule which, upon microscopic examination, can be seen to open via a central fine pore. Although it is most clearly visible in these two species, the nodule is also clearly apparent in both sexes of N.elegans, and in the females of N.leptocheles, N.longitarse, N.macrum and N.sluiteri, but to a lesser degree.

Such structures have been observed previously within the genus Nymphon. Meinert (1899) described the structure believing it to be a sense organ, possibly of hearing. Dohrn (1879) and Hoek (1881) both consider that the structure is glandular. Hoek describes it as consisting of a true glandular part, opening via a constriction into a sac-like receptacle which in turn opens to the exterior via the fine pore. No function has been attributed to this structure by either of these two authors, but since the gland is located on a reproductive appendage it may be the site of production of a chemical attractant akin to the pheromones of other arthropodan groups. A detailed histological and histochemical examination would be needed to shed light on the structure and function of the nodule.

The larval phase, within the Pycnogonida, is non-pelagic. It is therefore of considerable selective advantage for the animals to nurse their eggs and larvae. To have the eggs and young in a mass, protected by the parent, not only reduces the chances of predation but also, because the larvae are non-pelagic, enhances dispersal by the movement of the male away from the site of mating.

The longer a larva can remain attached to a parent, the greater are its chances of survival. The habit has reached its greatest development in Boreonymphon robustum, in which the larva develops within the egg and hatches directly into a juvenile which remains attached to the parent until fully developed. Indeed, in this species the young do not leave the parent until they are almost fully mature.

Brooding may have an additional survival advantage for species having a parasitic larval phase in that the parent can deposit the young within the host.

The origin of the nursing habit amongst pycnogonids is still in debate. Hedgpeth (1954b) believes that it may have had it origin in a primitive hermaphroditic condition, which is now represented by only a single species, Ascorhynchus corderoi. Bouvier (1923), however, considers that this function of the ovigers has been secondarily acquired and that the colossendeids, which do not nurse their eggs, exhibit the primitive condition.

The marked sexual dimorphism of the Eastern Arctic Nymphon species is very useful in distinguishing between the sexes in such species as N.longitarse and N.grossipes, where the gonads cannot be clearly seen.

The morphological diversity amongst the male ovigers provides a good taxonomic feature with aids in the clarification of the genus within the area. The interspecific distinctions between the

majority of species of Nymphon are very small, the clearest often being sexual ones, particularly the male ovigeral adaptations. For this reason it is far easier to distinguish between males of different species than between the females. This fact prompted Gordon (1932) to construct a suplementary key of Antarctic Nymphon species, for males only, around the specific differences in oviger morphology.

TABLE 4.1.1. COMPARISON OF OVIGER MORPHOLOGY OF EASTERN ARCTIC *NYMPHON* SPECIES. (IN MILLIMETRES).

SPECIES.	4th SEGMENT		5th SEGMENT.		
	MEAN LENGTH FEMALE : MALE	MALE % INCREASE	MEAN LENGTH FEMALE : MALE	MALE % INCREASE.	FURTHER ADAPTATION OF MALE OVIGER.
GROUP.I					
N.HIRTUM	1.20 : 1.24	3.33	1.60 : 2.52	57.50	None.
N.MEGALOPS	2.88 : 2.92	1.38	2.92 : 5.00	71.23	None.
N.SERRATUM	2.92 : 3.04	4.11	3.63 : 5.04	38.80	None.
GROUP.II					
N.LONGIMANUM	1.63 : 1.90	16.56	1.66 : 1.90	14.55	Entire oviger enlarged.
N.STROMI	3.84 : 4.90	27.60	3.84 : 5.04	38.80	Entire oviger enlarged.
GROUP.III					
N.ELEGANS	1.44 : 2.40	66.67	2.54 : 4.52	77.95	None.
N.LONGITARSE	1.69 : 2.00	18.34	1.57 : 2.02	28.66	None.
N.MACRONYX	1.19 : 1.43	20.16	1.25 : 1.62	29.60	5th segment curved through 90°.
N.MACRUM	1.55 : 2.10	35.48	1.50 : 2.65	76.67	5th segment curved through 90°.

TABLE 4.1.1. (continued).

GROUP IV.					
N.GROSSIPES	2.28 : 3.94	40.72	2.85 : 3.24	20.00	5th segment distally swollen.
N.MICRORHYNCHUM	1.25 : 1.81	44.80	1.25 : 1.82	45.60	5th segment distally swollen.
N.SLUITERI	2.09 : 3.04	45.45	1.90 : 3.04	60.00	5th segment distally swollen.
GROUP.V					
N.LEPTOCHELES	1.80 : 2.40	33.33	1.86 : 2.80	50.53	5th segment with row of nodules, 6th segment with row of serrations, both on inner edge of oviger.
N.HIRTIPES.	1.95 : 2.46	26.15	1.86 : 2.93	57.52	5th segment with heavily setose median and distal bulges.
N.TENELLUM	1.31 : 1.67	27.48	1.24 : 2.26	82.25	5th segment with setose median and distal bulges.

FIGURE 4.1.1.

Nymphon megalops.

a. Shepherd's crook (x50).

b. Male oviger (x12).

c. Female oviger (x12).

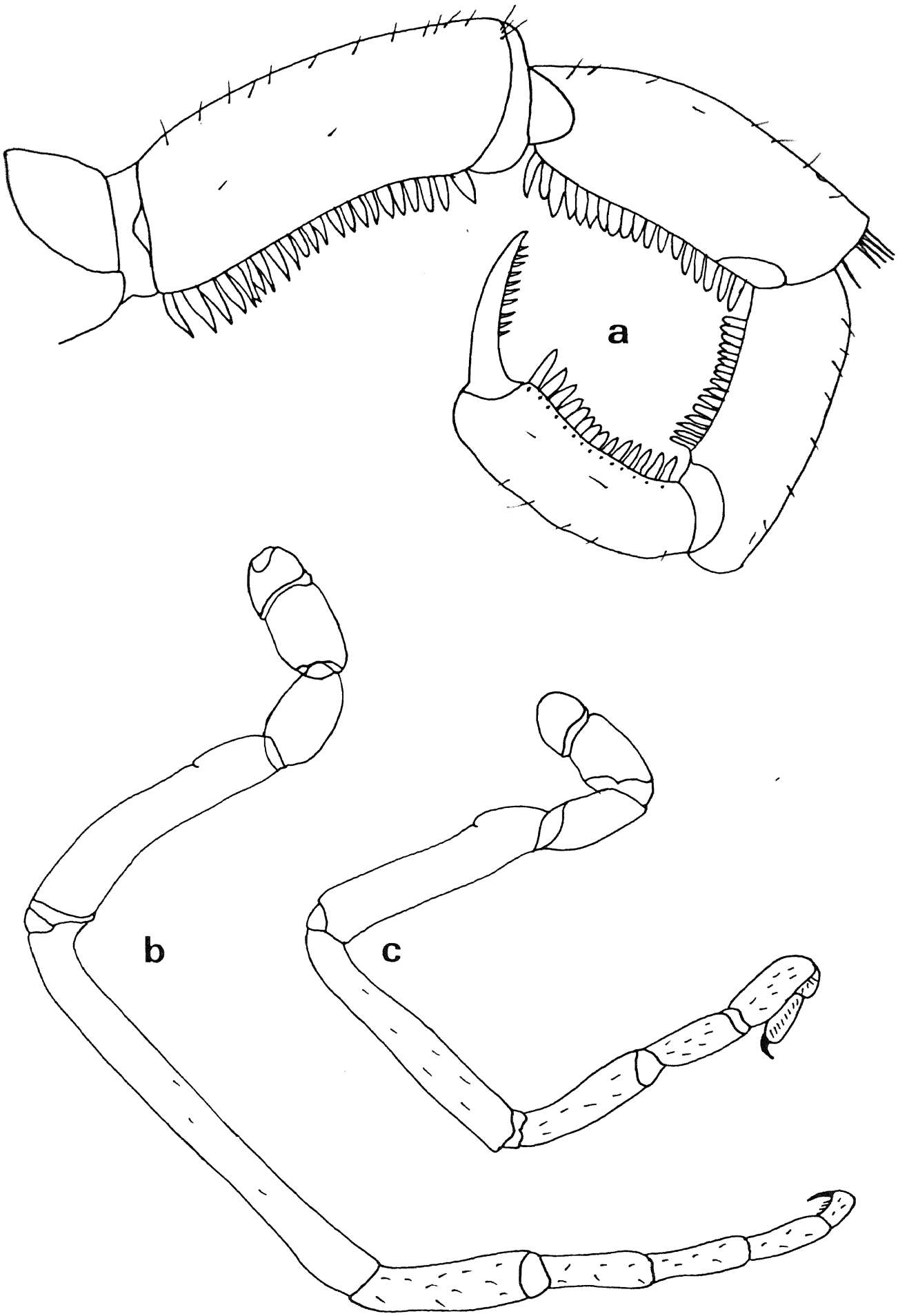

a
b
c

FIGURE 4.1.2.

Nymphon strömi.

a. Male oviger (x12).

b. Female oviger (x12).

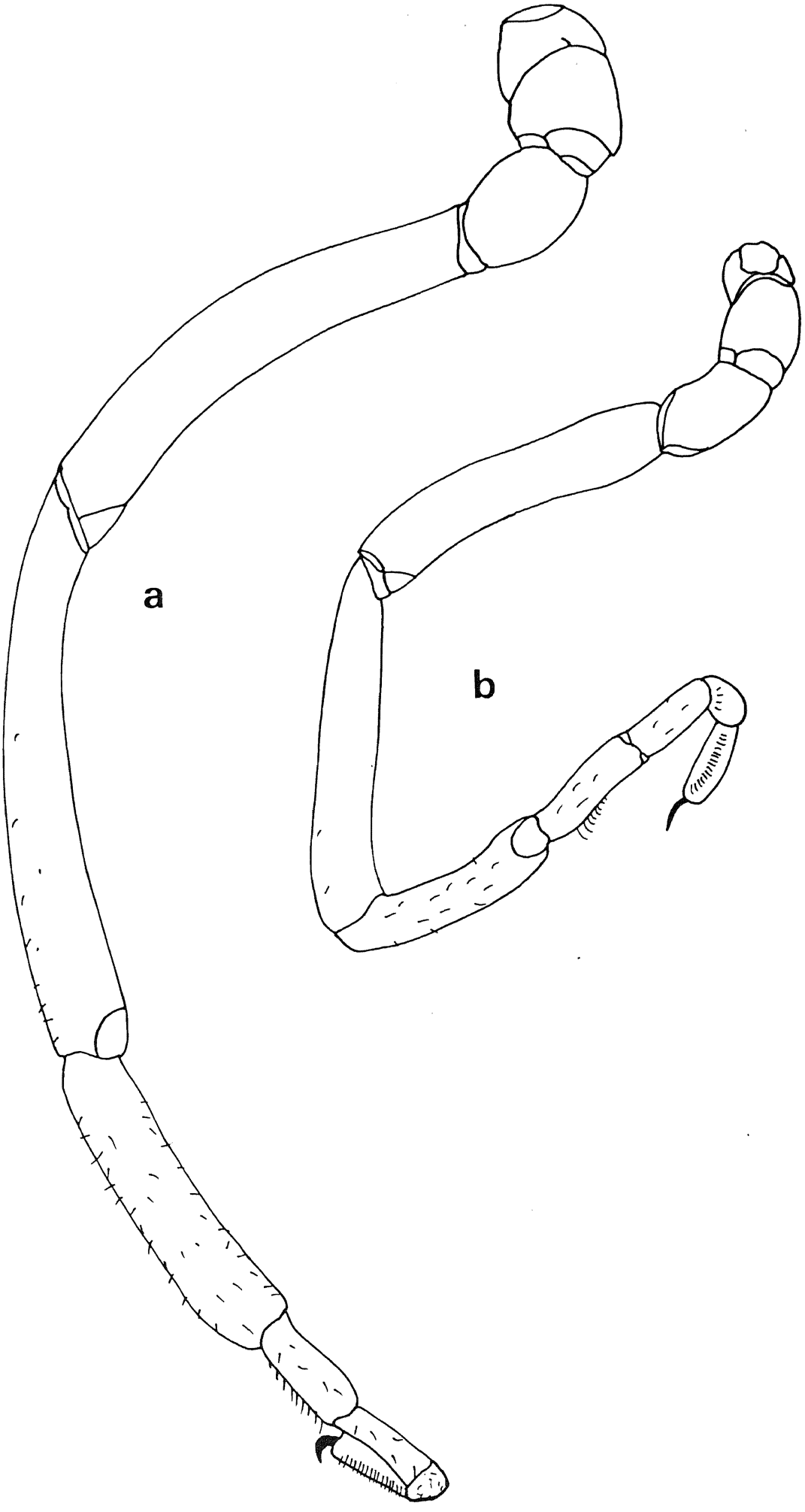

a
b

FIGURE 4.1.3.

Nymphon macrum.

a. Male oviger (x25).

b. Female oviger (x25).

Nymphon sluiteri.

c. Male oviger (x25).

d. Female oviger (x25).

N.B. Only fourth, fifth and sixth segments have been represented.

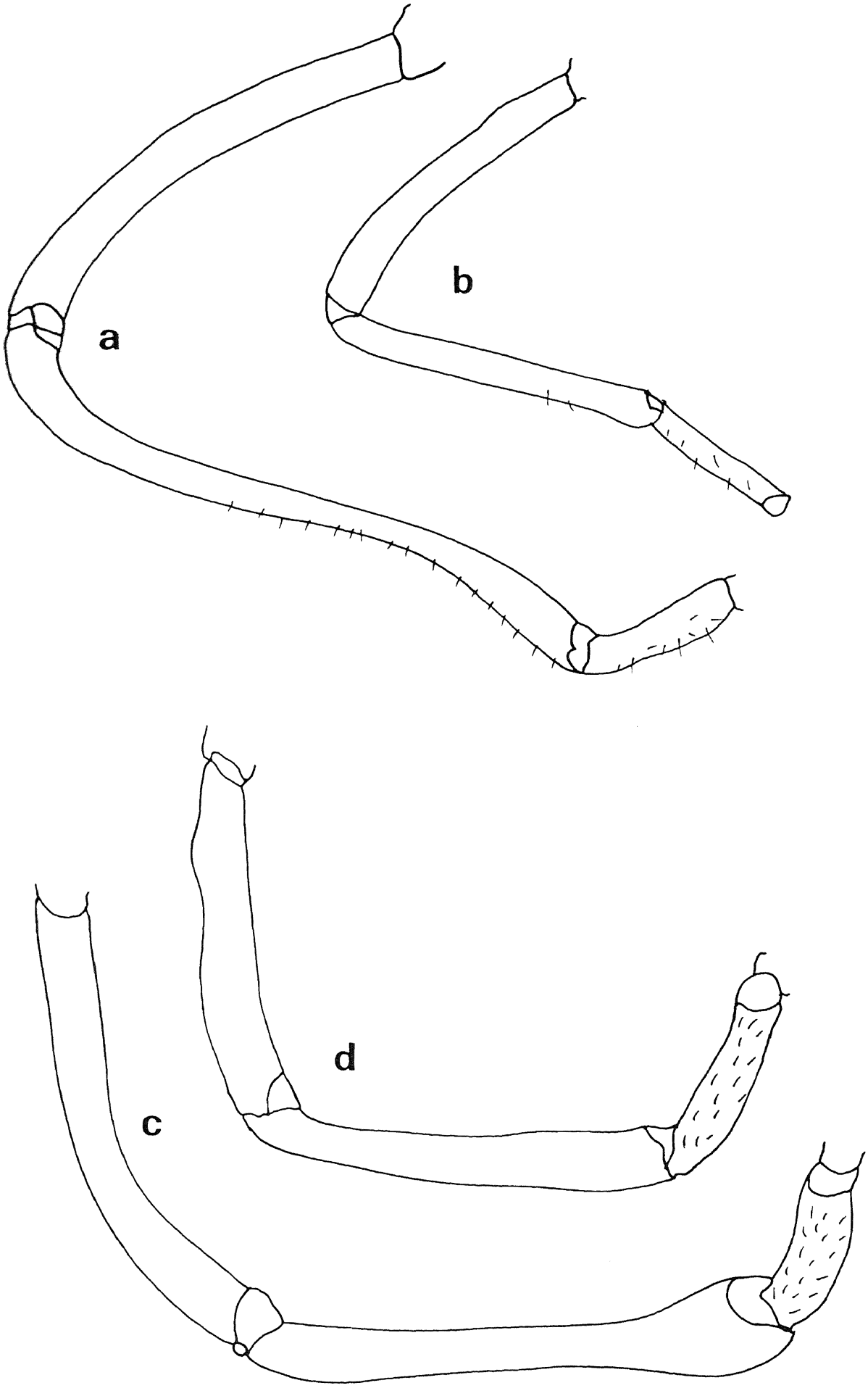

a
b
c
d

FIGURE 4.1.4.

Nymphon leptocheles.

a. Female oviger (x25).

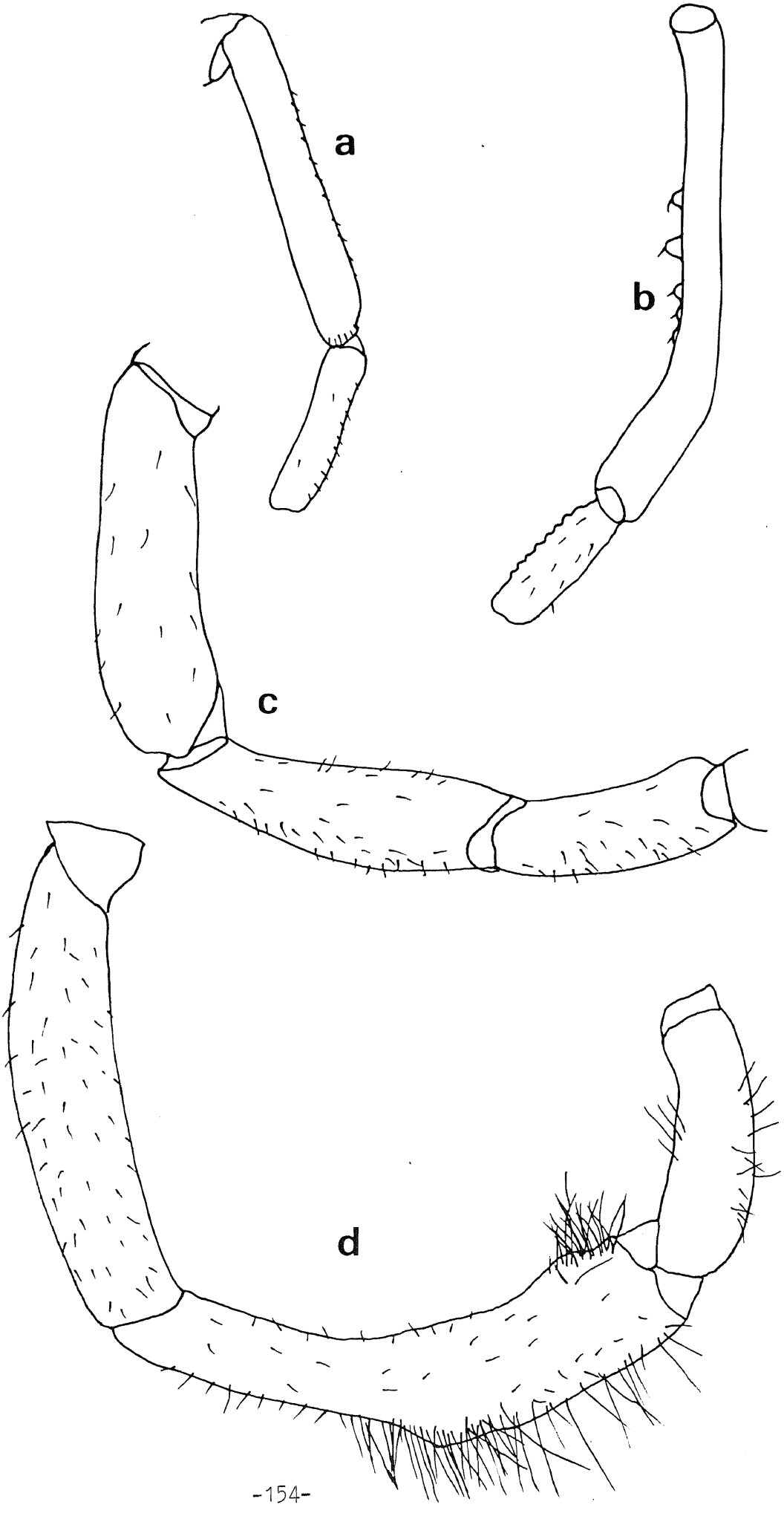
b. Male oviger (x25).

Nymphon hirtipes.

c. Female oviger. (x12)

d. Male oviger (x12).

N.B. Only the fourth, fifth and sixth segments have been represented.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4.2 CEMENT GLANDS.

All eight pycnogonid families are known to possess cement (or silk) glands.

Dohrn (1881) first described their presence and possible function, noting that within the genus Phoxichilidium (including Anoplodactylus) the males have a single pore-like opening on the fourth or femoral segment of all walking legs. These he called Kittdrüsen (= cement glands) and presumed their function to be glandular, probably producing the adhesive used to bind the fertilized eggs together and to secure them in spherical masses to the male ovigers after mating.

Between genera there is a considerable variation in both the number and position of the pores. Tanystylum, Phoxichilidium and Anoplodactylus typically have a single pore positioned dorsally, usually at the tip of a conical tubercle. Eurycyde also has a single pore, but the position varies between species, being either dorsal or ventral and in one species, E.curvata (Child, 1978), posteriolateral. In Colossendeis the pores are numerous and scattered over the entire ventral surface whereas in Ascorhynchus and Nymphon they are arranged in a single line in mid-ventral position. The exception within Nymphon is N.tubiferum (Stock, 1978) which has only a single ventral pore mounted on the end of a long spigot.

Hoek (1881) first investigated the internal structure of the glands. He found that they were composed of a skeletal matrix of connective tissue with glandular nucleated cells filling the interstices. When the glandular material completely filled the spaces, the skeletal matrix was often obscured.

The shape of the cellular mass differs between genera although the cellular composition is similar. In Nymphon and Ascorhynchus it forms a single compact mass, lying on the ventral surface, entirely in the femur in Nymphon and extending into the first tibia in some species of Ascorhynchus. The external pores, although in most genera restricted to the femur, may be present as far down the leg as the second tibia, as has been reported in Ascorhynchus (Stock, 1975). In Colossendeis, instead of a single glandular mass, there are numerous isolated patches of tissue, each attached to a single pore. The shape of the glandular cells also differ between genera according to Hoek. Those of Ascorhynchus are fusiform whilst in Nymphon they are globose, but in both genera they are distinctly nucleated. In all genera studied the glandular mass or masses have a well defined nerve plexus.

Hoek found that mature males of a few species, including Nymphon grossipes had no glandular pore openings. This he assumed was an indication that their presence was seasonal, being present only during the breeding season. Like Dohrn, Hoek concluded that the function of the cement glands was to secrete the egg binding adhesive.

From personal observation of the fifteen species of Eastern Arctic Nymphon, it is clear that the males of all species have cement glands with pores lying in a single mid-ventral line on the femora of all walking legs.

In most, including Nymphon grossipes, N.strömi and N.elegans, the only discernible external evidence of the glands is a row of minute pores. The difficulty of detecting the femoral pores could have been why Hoek (1881) overlooked them. In a few species, such as N.hirtipes and N.tenellum ,their presence is more obvious, appearing

as a row of flat-topped nodules, each with a pore on the crown. (Figs 4.2.1a & c).

However, a few specimens of Nymphon hirtipes, although possessing well developed femoral nodules, had round rather than flat crowns. On closer inspection they were found to lack the central glandular pore.

A histological examination of the femoral cement glands was made to discover if there was any internal morphological difference between the two.

Fresh specimens of Nymphon hirtipes were narcotized in ethyl acetate for two hours and fixed in sea-water Bouins solution for 24 hours before being transferred to 10% neutralized formol saline solution.

Tissue for histological examination was then selected, femora with open and closed glands were washed in distilled water for 24 hours to remove any formalin salts prior to dehydration in successively higher concentrations of alcohol and embedding under vacuum.

A major difficulty in the preparation of pycnogonid tissue for histology is the hard, thick and relatively brittle cuticle which, unless sufficiently dehydrated and embedded, shears out of the embedding block when it is sectioned, breaking the soft internal tissues.

Various embedding media were tried, including the ester waxes 1947 and 1960 (Steedman, 1960) which have a harder and more crystalline composition than ordinary paraffin wax. These proved unsuccessful, the greater crystalline structure increasing the

shearing effect. Eventually, paraffin wax (melting point 58°F) was used, but to produce a harder block which would prevent shearing and improve ribboning it was cooled for fifteen minutes before any attempt was made to section it.

Sections were cut with a Cambridge rotary microtome, Type 52164, with the knife set at an angle of fifteen degrees. The sections were between eight and eleven microns thick, nine being most common. Sections cut at nine microns produced excellent ribboning, with the minimum of compression of tissue. Both longitudinal and transverse sections were clear and of good standard at this thickness.

After sectioning, the ribbons were floated onto glycerine albumen coated slides and dried at 37°C. The soft internal tissue and the paraffin wax embedding media both adhered efficiently to these coated slides. However, the thick cuticle did not adhere to the slides and to avoid losing it during staining the slides were further coated with a thin film of 1% celloidin in a 50/50 mixture of ether and absolute alcohol after dewaxing in xylene.

All sections were then stained in Mallory's triple stain and mounted using Euparal, this method being best for a preliminary examination of the histological structure of the cement glands.

The internal structure of the cement glands of Nymphon hirtipes coincides with the description given by Hoek (1881) for Nymphon. The glandular mass of tissue lies along the proximal two-thirds of the ventral surface of the femoral segment in each leg, the proximal end being the wider. The glandular mass has a connective tissue structural matrix which takes up Mallory's triple stain. The matrix is filled with glandular tissue composed of numerous nucleated globose cells containing protein. From these sites of protein

production, ducts can clearly be seen leading to the external open pores on the raised mounds of the ventral surface. Nervous tissue is present throughout the entire mass. Figs 4.2.2a & b show comparative sections from open and closed cement glands. The open glands have a muchthicker layer of subhypodermal glandular tissue which includes clearly detectable sites of glandular activity. In contrast, the subhypodermal layer of the closed femora is very thin, showing little or no sign of glandular activity.

This preliminary histological examination, although using a standard technique, has nevertheless corroborated the earlier work of Hoek and given an insight into the relationship between the state of the glands and pores and the maturity of the individual. A detailed histological and histochemical examination would be required to determine the precise nature of the glandular cells and the chemical composition of the adhesive.

TAXONOMIC SIGNIFICANCE OF PORE NUMBERS.

Nymphon hirtipes and N.tenellum are morphologically similar species with the major difference between the two being one of maximum adult size; N.tenellum is considerably smaller when fully developed.

The femoral cement nodules in both species are detectable without the aid of a microscope. Sars (1891) recorded the number of pores in both species and found them to be different.

In order to establish the taxonomic significance of the pore numbers a census was made using forty adult male N.hirtipes and twenty N.tenellum.

The pores in all these specimens were counted and the mean number

per leg determined. This was then plotted against total leg length for each specimen to give an indication of the relationship between pore number and animal size. (Graph 4.2.1).

The variation in pore number from limb to limb in any one individual is slight.

There was a direct correlation in both species between animal size and pore number (Graph 4.2.1.). The difference in adult size between N.hirtipes and N.tenellum is clearly reflected by the pore numbers. For N.tenellum the range lies between two and five pores per leg, whereas among specimens of N.hirtipes the range is between six and thirteen pores per leg.

The species description of N.hirtipes recognizes both a large and a small size morph, as set out in section 2. This too is clearly represented within the pore census, the small morph has six to eight pores on each leg,and the large one seven to thirteen.

All specimens of Nymphon hirtipes carrying either maturing egg masses or young on the ovigers, and obviously in a state of full sexual maturity, have been found to have open femoral pores. This implies that those specimens in which the pores are closed are not fully sexually mature, although from the state of oviger development and, in some specimens, the fully open genital pores, they may appear to be. A further moult must therefore intervene before the femoral pores attain the open state and there must also be a sudden increase in the glandular tissue of the subhypodermis during the period just prior to the final moult.

So alike are Nymphon hirtipes and N.tenellum that Meinert (1899), Appellof (1910) and Schimkewitsch (1930) suggested that the two species be amalgamated under a single specific epithet. However, the

results of this census show no overlap between the two ranges of femoral cement pore numbers and is therefore evidence that these are two distinct species. In addition, the femoral pore numbers can be used to distinguish between the males of N.hirtipes and N.tenellum , a feature which has been used with success in the systematics of Endeis (King, 1974) and Ascorhynchus (Stock, 1975).

The ranges of the pore numbers of the two size morphs of N.hirtipes do overlap however, and these should not therefore be awarded distinct sub-specific or specific status. The size variation is probably attributable to a difference in environmental conditions rather than to a genetic difference. .

The histological study of the cement glands of N.hirtipes has provided evidence that specimens having rounded, rather than flat-topped, femoral nodules are not sexually fully mature. Externally, the specimens lack pores on the femora and internally, the sub-hypodermal tissue shows little or no signs of glandular activity. Thompson (1909) reports that, in most species, the pores appear for the first time at the last moult before maturity is attained and Nakamura (1981), in a study of the post-embryonic development of Propallene longiceps, adds that the femoral cement glands have several openings which appear only at, or after, the tenth and last moult.

In all genera, except Colossendeis, the internal glandular structure is similar, appearing as a single compact mass of tissue within the femur and occasionally the tibia of the walking legs (Hoek, 1881). In Colossendeis, the tissue appears as a collection of distinct isolated patches, each leading to a separate external pore. This, as in other morphological anomalies peculiar to colossendeids

such as gonad and terminal leg morphology, could be indicative of a primitive condition.

The composition and mechanism of release of the adhesive produced by the cement glands is unknown. It is possible that it may be similar to the silk produced by terrestrial spiders, which is a scleroprotein, extruded as a liquid and hardening, not from exposure to air, but from the actual extrusion process itself. The mechanism of release must be associated with the mating process, possibly being triggered by the release of sperm. There is an abundant nerve supply throughout the glandular mass.

After fertilization has occurred in Propallene longiceps and the eggs have been transferred from the female to the male ovigers, Nakamura and Sekiguchi (1980) have observed the male, which lies upside down, to move his ovigers actively, secreting cement from the glands and covering the newly fertilized eggs, which are at the base of the ovigers, in a pool. Using the four terminal ovigeral segments, he then removes the cement covered eggs, one by one, and secures them in bracelets of eight to the long segments of his ovigers. The cement solidifies within 24 hours.

The variation in the position of the cement pores in different genera suggests that there may be differences in sexual behavior. If the primary function of the secretion is to glue the fertilized eggs together then the position of the pores must be important. Present knowledge of mating behavior in pycnogonids is limited to a few coastal species and further studies like that of Nakamura and Sekiguchi (1980), is needed to discover whether the position of the cement pores bears any significance to the relative positions taken up by the animals during mating.

GRAPH 4.2.1. VARIATION IN CEMENT NODULE NUMBER WITH ANIMAL SIZE.

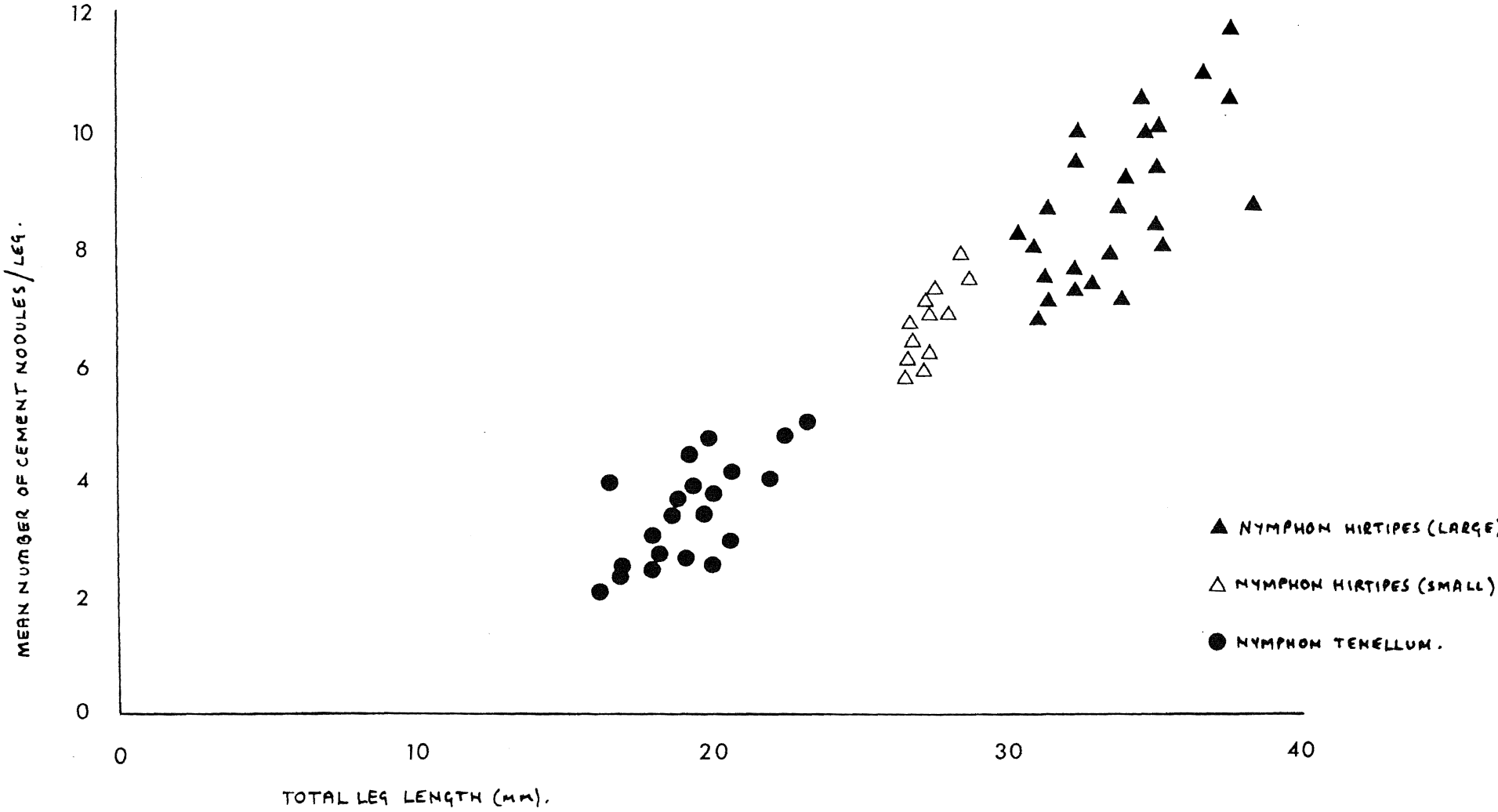


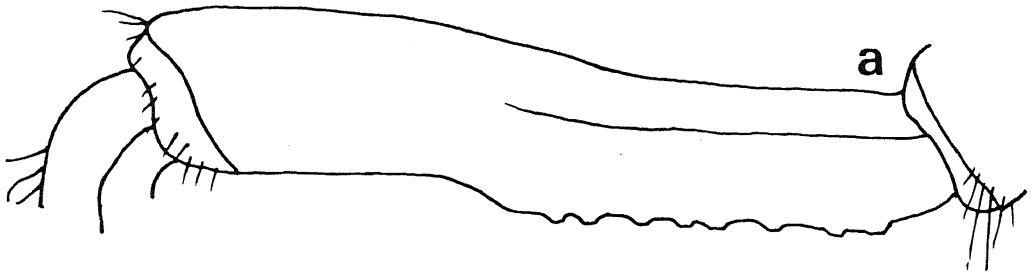
FIGURE 4.2.1.

MALE FEMUR OF NYMPHON HIRTIPES.

a. (x12). Cement nodules are flat-topped possessing central pore.

b. (x25). Cement nodules are rounded and lacking central pore.

c. (x50). High power view of open cement nodules.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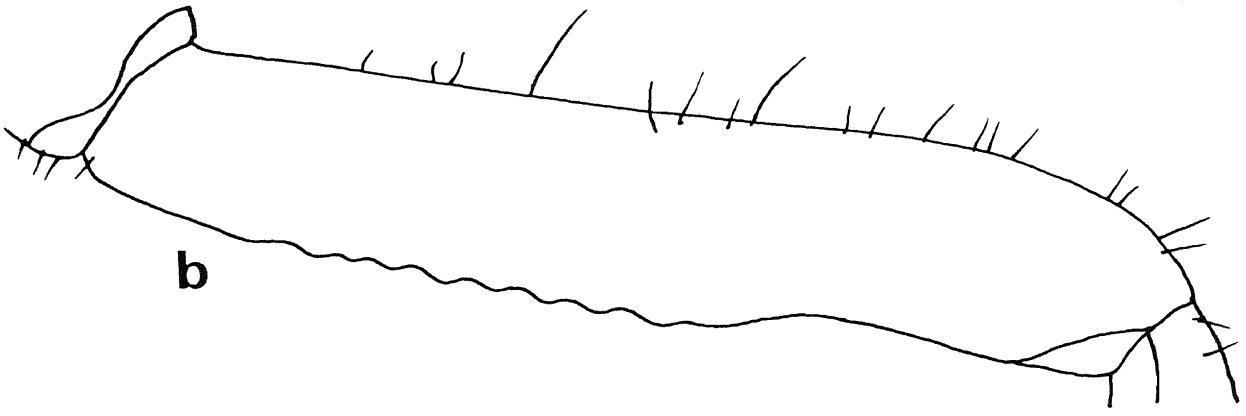
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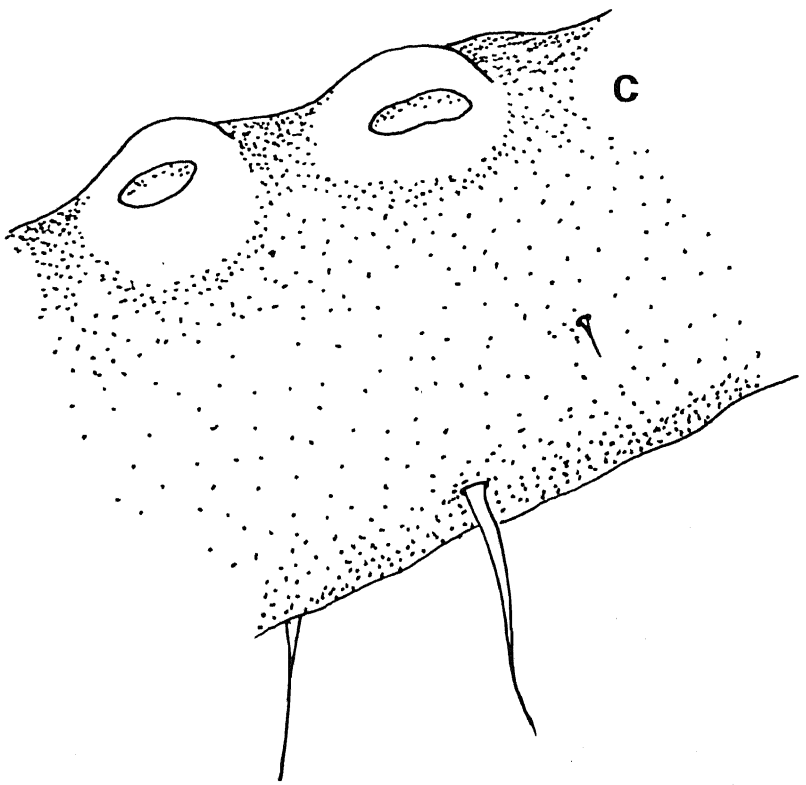

c

FIGURE 4.2.1

a. V.L.S. Femur .Mature male Nymphon hirtipes.

b. V.L.S. Femur. Male, final larval stage. Nymphon hirtipes.

c. gut caecum

g. glandular material

i. integument

n. cement nodule

m. muscle fibres.

c. V.L.S. High power section of (a)

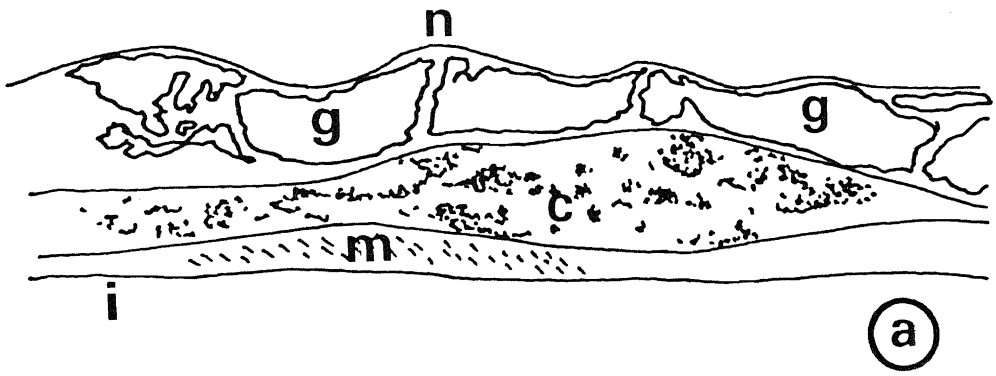
d. duct ?

g. glandular material

i. integument

p. pore

v. storage vesicles ?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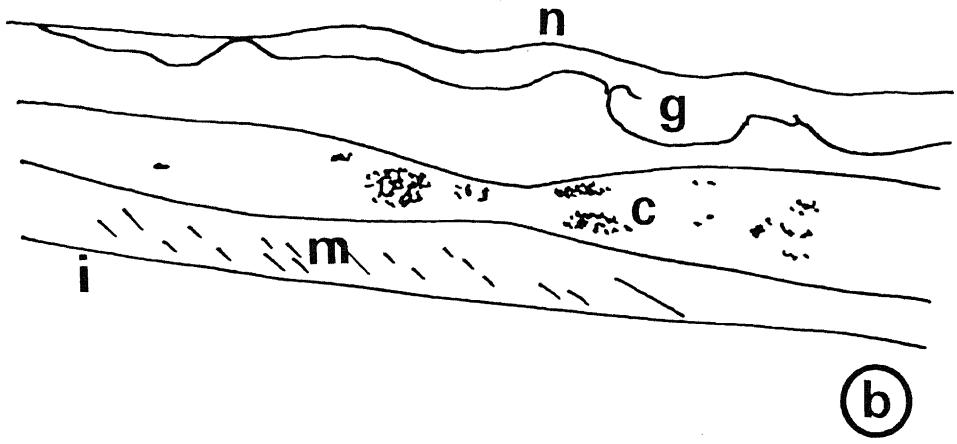
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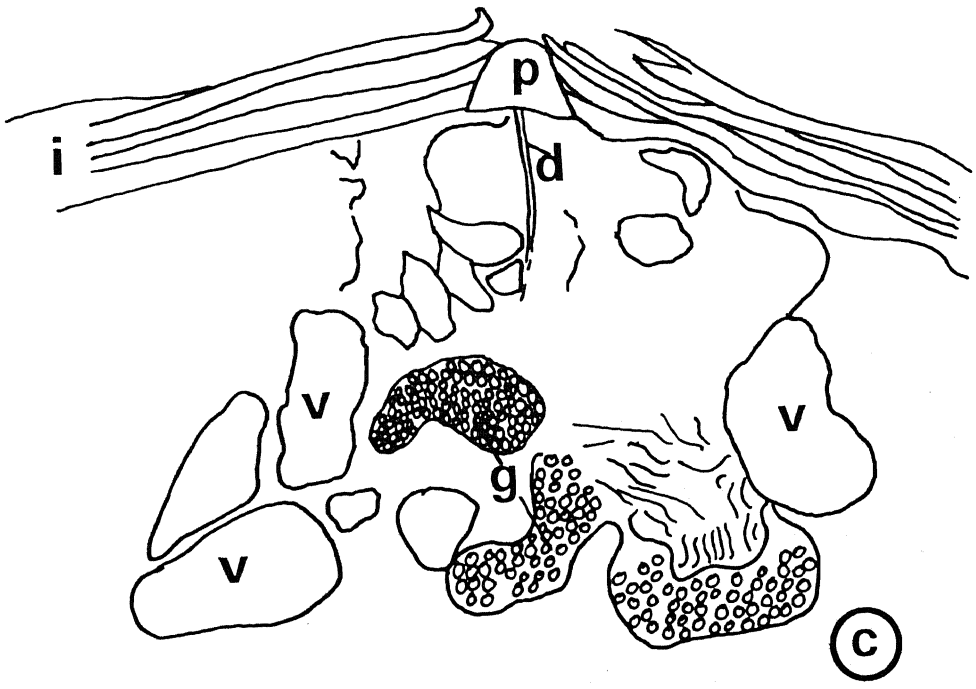
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4.3. REPRODUCTIVE BIOLOGY.

The fecundity of the Pycnogonida has been examined in a number of different genera. Detailed accounts of oögenesis have been published by Sanchez (1959) and Jarvis and King (1978) and of mating by King (1972) and Nakamura and Sekiguchi (1980).

Jarvis and King (1978) report that Pycnogonida produce relatively few eggs and that the number of eggs maturing at any one time within an ovary varies between genera. Sanchez (1959) found that all the eggs matured together within a single femur of Endeis spinosa Montague, 1808, whilst for species of Callipallene Flynn, 1929 (Sanchez, 1959) and Propallene longiceps Bohm, 1897 (Nakamura and Sekiguchi, 1980) only two eggs matured within a femur at any one time.

It was Cavanna in 1876 who first demonstated that it is the male and not, as had been thought, the female which receives the eggs after mating and fashions them into ovigeral masses.

Hoek (1881) noticed that both within and between species the size of the ovigeral egg masses on the male vary considerably, being dependent on the size and number of eggs present.

For example, each ovigeral egg mass represents the entire ovulation of one female in Phoxichilidium femoratum Rathke, 1799 (Helfer & Schlottke, 1935) whereas for Endeis spinosa a similar mass represents the contents of only a single femur (Sanchez, 1959). In Propallene longiceps each ovigeral mass comprises a number of bracelets. A single bracelet contains eight eggs, which is the total complement of mature ova from either the four left or the four right femora (Nakamura and Sekiguchi, 1980). Each bracelet is thus the result of one mating with a single female and represents half

of her total egg complement. It follows from this that the entire ovigeral mass must be the result of a number of matings with different females.

Both the number of ovigeral egg masses being carried by a single male and the number of eggs which each egg mass contains vary between species. Hoek (1881) recorded that only a single mass was carried at any one time by Ascorhynchus minutus. However, he added that this was probably not the usual case, having observed a number of other species with two or more masses on each oviger. The maximum number of egg masses recorded on a single specimen is fourteen, this for Phoxichilidium femoratum (Helfer and Schlottke, 1935).

Pycnogonid species can be classed broadly into three groups with repect to egg size, which is determined by the amount of yolk present. Anoplodactylus petiolatus and Phoxichilidium femoratum produce small, lightly yolked eggs (Helfer and Schlottke, 1935), the Nymphonidae and Callipallene species have large, heavily yolked eggs (Jarvis and King, 1978; Helfer and Schlottke, 1935) and the Ammotheidae and Endeidae have moderately yolked eggs which are intermediate in size (Jarvis and King, 1978).

The length of time for which the male carries the larvae varies between species. Some deposit very young larvae upon vectors, such as hydroid polyps, only a short time after hatching, whereas others keep charge of their larvae for longer periods. Although it has not been observed in Antarctic species, Hedgpeth (1963) noted that the males of two high arctic Nymphon species (N.hirtipes and N.sluiteri) carry their developing young until the fifth or sixth larval instar, when only the fourth pair of legs remain undeveloped, a stage also described as the sub-adult. The pan-arctic species Nymphon grossipes

has been found to do the same (personal observation). In the other high arctic species of the Nymphonidae, Boreonymphon robustum, 'parental care' is more marked. The eggs hatch directly into juveniles because the entire larval development takes place within the egg. After hatching they remain on the parent until they have grown to about one-third adult size.

Initial observations of the fifteen species of Eastern Arctic Nymphon revealed that large interspecific variations exist in both size and number of ovigeral egg masses carried on the males. To expose the extent of this variation a study was undertaken of the mature ova within the ovary, and of the fertilized eggs present in the ovigeral masses on the male.

These species vary considerably in abundance. N.hirtipes and N.strömi are by far the most common, making them natural choices for study. For both, twenty males with ovigeral egg masses and twenty females having mature ova within their ovaries were selected for study. Four other species; N.elegans, N.macronyx, N.serratum and N.tenellum were included for comparison. These are less abundant species and only five specimens of each sex were available for study.

All specimens were collected from the West Spitsbergen fishing grounds in the summers of 1978 and 1979. All the material was initially fixed in 5% formol saline and finally, after washing in distilled water for 24 hours, transferred to 70% ethyl alcohol.

The size of each individual was determined by taking the total length of the third left walking leg. Both eggs and ovigeral masses were, for the purposes of this study, assumed to be spherical, this being a slight but acceptable approximation.

For each male, the egg masses were counted and their diameter measured. They were then individually removed from the oviger, broken up using fine forceps and the number of eggs present counted. The diameter of ten, randomly selected eggs, was measured.

Examination of the ova within the female necessitated the dissection of each femur. First, all femora were removed from each specimen. The cuticle of each was cut open along the ventral margin and the entire ovary extracted. The eggs were then removed by rupturing the ovary wall with a dissection needle.

Only mature eggs were analysed. In situ these usually lie on the ventral margin of the femoral ovary. They are readily distinguishable by their size, since they contain a full complement of yolk, and by the distinctive orange colouration of the fibrous outer coating. Immature eggs are off-white in colour. Mature eggs within each ovary were counted and , as with the male, the diameter of ten was measured.

The species of Nymphon from the Eastern Arctic can be classified into two distinct groups with respect to their general morphology. First there are those species, such as N.strömi, which have a graceful shape, often with terminal leg segments suited to a striding habit, and second, the robust species, exemplified by N.hirtipes, which have terminal leg segments suited to a clinging habit.

There is a good correlation between these two types and egg mass number (Table 4.3.1.), the males of the robust,clinging species (N.hirtipes, N.macronyx and N.tenellum) carry one, two and occasionally three egg masses, whereas the males of the graceful forms (N.elegans, N.strömi and N.serratum) carry two, three and often as many as five.

Where more than one ovigeral mass are present are present, they are always at different stages of development; some being recently laid whilst others are begining to hatch. All embryonic development in pycnogonids takes place within the inelastic fibrous coating of the egg, which is ruptured only on hatching.

For any one species the sizes of both the unfertilized ova and fertilized eggs are similar, although there is considerable variation in the sizes of mature eggs of different species (Table 4.3.2.).

Egg size appears to be correlated with the number of egg masses carried by the male. Those species with only a few egg masses (N.hirtipes, N.macronyx and N.tenellum) have large yolky eggs with a size range of 0.6 to 0.8 mm, whereas the others produce much smaller eggs. N.strömi and N.serratum each have an egg size range of 0.14 to 0.24mm, whilst N.elegans is intermediate in size with a range of 0.32 to 0.44 mm. Because the eggs vary little in size and because both eggs and egg masses are spherical, the egg mass size in all species shows a direct correlation with the number of eggs it contains.

The number of eggs carried in an ovigeral mass is not constant within a species. However, the variation is small compared with that shown between species. This is well illustrated by the two most abundant species. In N.hirtipes an egg mass contains about 150 eggs whilst N.strömi has 4,500. Of the remaining species under consideration, N.serratum has an ovigeral egg mass number similar to that of N.strömi whereas N.elegans, N.macronyx and N.tenellum all have about the same number as N.hirtipes.

There is ample evidence that these species of Nymphon do not all produce large heavily yolked eggs. N.hirtipes and N.tenellum

do have large heavily yolked eggs but N.strömi and N.serratum have small eggs containing only a little yolk and those of N.elegans are of intermediate size.

The eggs of Nymphon mature in batches; when one has been laid another comes to maturity. Consequently, there is no apparent correlation between female size and the number of mature eggs present within an ovary. The samples were collected during a period of five weeks in summer and whilst some females were found to have a full complement of mature eggs others, which had presumably recently laid a batch, had few. A more accurate determination of egg production would call for the continuous study of a species for a period of at least a year, which in polar areas is impractical because of the harsh climatic conditions during the winter months.

Mating has not been observed for any species of Eastern Arctic Nymphon but an ovigeral egg mass has been assumed to represent the entire oviposition of a single female. The number of mature ova in a female is closely correlated in all these species with the number of fertilized eggs in an ovigeral egg mass. Observations of hatching have shown that all eggs in any one mass hatch within a short period of time.

Nakamura (1981) has shown that Propallene longiceps has an embryonic development of approximately seven days, this being constant for all eggs examined. The eggs are laid simultaneously and it follows, therefore, that they must hatch together (Nakamura and Sekiguchi, 1980). In Nymphon there is synchrony in the hatching of an egg mass and, assuming that the time for embryonic development is constant, all eggs within an ovigeral egg mass must have been laid simultaneously, and thus, at a single mating.

The length of time for which larvae of different species of Nymphon remain attached to the ovigers varies. In N.strömi and N.serratum the larvae are lost from the parent at about the third instar stage, whereas, as stated above, those of N.hirtipes remain clinging to the ovigeral setae with their chelae for the major part of their post-embryonic development.

It is not known whether the larvae of N.hirtipes are deposited upon the polyp of a hydroid vector, or whether they are shed from the oviger to continue a free living development on the substratum. The shallow water species Anoplodactylus petiolatus is known to deposit its larvae upon Campanularia flexuosa (Dogiel,1911), where the post larval development is completed parasitically.

This raises the question of how larvae of species such as N.hirtipes obtain their nutrition (Hedgpeth, 1963). In species which retain their larvae for long periods large heavily yolked eggs are produced, the yolk within each being sufficient to sustain the larva through the early stages of post-embryonic development. In species which produce smaller, less yolky eggs, the larvae remain on the ovigers for only a short period of time before they are lost, presumably because their yolk reserves are exhausted and they must, therefore, seek other sources of nutrition.

The habit of nursing the larva for the majority of its post-embryonic development has been recorded for high arctic species only. It is, therefore, likely that it is a cold water survival adaptation. In warmer and shallower water species the habit of having a parasitic larval phase appears to be favoured.

In Boreonymphon robustum , in which the eggs are very yolky and the juveniles remain on the parent until one-third adult size, it is

possible that the larvae develop sufficiently on the yolk reserves alone to reach a stage at which they can feed independently whilst still clinging to the male.

The chances of survival increase with the length of time that the larva remains on the parent, since the chances of predation are greatly reduced. The major factor limiting this is the amount of yolk in the egg at oviposition. When this is exhausted the larva must leave in order to avoid starvation.

All the species of Nymphon which occur within the Eastern Arctic experience a stable marine environment and have a slow rate of both development and reproduction. It could be argued that all of them conform well with the K strategy of survival postulated by Pianka (1970), although two different reproductive strategies are recognizable amongst the species studied. Both of these strategies represent different ways in which the genus has exploited its stable environment.

One group of species, which includes N.strömi and N.serratum, is well adapted for walking and consequently likely to browse over a wide area. It follows that their chances of survival depend in part upon their ability to produce sufficient young with which to 'seed' their habitat. These species meet this requirement by producing large numbers of eggs (often over 4,000) each of which receives only a small proportion of the total yolk output. The males carry between two and three ovigeral egg masses at any one time, representing a total of between 8,000 and 12,000 eggs. Consequently, the young which hatch from these eggs can remain on the male ovigers for only a short period of their post-embryonic development before the scarcity of yolk forces them to leave.

The other group includes N.hirtipes, N.macronyx and N.tenellum. These species are less mobile than those of group one and enhance the survival of their progeny by producing a comparatively small number of eggs (50 - 200). Each, however, is endowed with a generous share of yolk as the total output is divided between fewer eggs. The males carry only one, and occasionally two, ovigeral egg masses which represents a total of between 100 and 400 eggs. The increased yolk complement prolongs the time in which the post-larvae can remain on the male, enjoying his protection, until they leave to take up an independent existence as almost fully developed individuals. Most of the juveniles are unlikely to disperse very far as the morphology of this group suits them better for clinging than for walking. Thus a small number of individuals, each with a good chance of survival is introduced into a small area.

At first sight N.elegans appears to be an intermediate species between the above two groups. It produces only a few eggs (about 40) but carries two to three ovigeral egg masses, a state of affairs similar to N.strömi. Egg size is also intermediate between the two extremes but being an exceptionally slender species the amount of yolk may be sufficient to support post-larval development to a relatively advanced stage. Therefore it would appear that N.elegans has a similar reproductive strategy to the species within the N.hirtipes group.

It is possible that each of the two patterns represents a divergence from a primitive form which produced a few eggs with little yolk. Looked at in this way, it is possible to see both as adaptations which would increase the chances of survival by permitting exploitation of the same environment in different ways.

TABLE 4.3.1. PERCENTAGE NUMBER OF OVIGERAL MASSES / MALE.

SPECIES	PERCENTAGE					MEAN
	1	2	3	4	5	
Nymphon macronyx	76	24	-	-	-	1.24
Nymphon hirtipes	71	25	4	-	-	1.33
Nymphon tenellum	73	20	7	-	-	1.33
Nymphon serratum	17	50	28	6	-	2.22
Nymphon elegans	11	50	28	11	-	2.39
Nymphon strömi	23	20	30	21	6	2.67

TABLE 4.3.2. MALE AND FEMALE MATURE EGG SIZE RANGES. (In millemeters)

SPECIES	MALE	FEMALE
Nymphon hirtipes	0.64 - 0.80	0.60 - 0.80
Nymphon tenellum	0.60 - 0.72	0.60 - 0.76
Nymphon macronyx	0.60 - 0.72	0.56 - 0.72
Nymphon strömi	0.16 - 0.22	0.14 - 0.24
Nymphon serratum	0.18 - 0.24	0.18 - 0.24
Nymphon elegans	0.36 - 0.44	0.32 - 0.44

TABLE 4.3.3. COMPARISON OF MEAN EGG NUMBERS IN MALE OVIGERAL EGG MASSES AND FEMALE OVARIES.

SPECIES	MALE (Ovigeral mass)			FEMALE (ovary)		
	Number sampled	Range	Mean	Number sampled	Range	Mean
Nymphon hirtipes	37	90 - 233	149	20	42 - 240	123
Nymphon tenellum	6	29 - 43	36	5	24 - 48	38
Nymphon macronyx	6	27 - 32	28	5	26 - 35	29
Nymphon strömi	75	1898 - 5912	4358	12	2737 - 5020	3790
Nymphon serratum	10	1420 - 1842	1670	12	1780 - 2808	1959
Nymphon elegans	12	18 -56	38	5	70 - 82	75

TABLE 4.3.4. EGG DATA.

SPECIES	MEAN NUMBER OF EGG MASSES / MALE	MEAN NUMBER EGGS / MASS	POTENTIAL RECRUITMENT.
Nymphon strömi	2.67	4358	11,635.85
Nymphon serratum	2.22	1670	3,707.40
Nymphon hirtipes	1.33	149	198.17
Nymphon elegans	2.39	38	90.82
Nymphon tenellum	1.33	36	47.88
Nymphon macronyx	1.24	28	34.72

4.4. LIFE HISTORY OF NYMPHON HIRTIPES

The complete life cycle is known for only a few pycnogonid species and of these most, like Propallene longiceps and Pycnogonum littorale, are either tidal or sub-tidal forms which are both easy to collect and lend themselves to study in laboratory conditions. Knowledge of reproduction in polar species is very limited and the life cycle of Boreonymphon robustum is the only one known completely.

Any study involving marine organisms from polar areas must incorporate a degree of conjecture because of the impracticability of biological sampling for at least six months of the year owing to adverse climatic conditions.

Nymphon hirtipes is the most abundant pycnogonid in the Eastern Arctic and this, coupled with the fact that the males retain the developing larvae for a long period makes it a suitable species for study. From observations of fresh and preserved material, reports in the literature and personal communications, a hypothetical life history has been constructed.

Samples of N.hirtipes were collected on the West Spitsbergen fishing grounds from June to September and a single sample was obtained from the West Greenland fishing banks in December. This latter sample was used because no material was available from West Spitsbergen for the winter months.

Most of the specimens collected were adults as the mesh size of the collecting gear was too coarse to retain the smaller specimens. The smallest juvenile collected was about half the mean adult legspan.

All the summer samples included males carrying ovigeral egg masses and females with mature or maturing ova. From this, although no pairs were discovered in copulo, it is evident that mating occurs

from June onwards, at least into September and perhaps beyond.

Jarvis and King (1978) report that shallow water pycnogonids are typical of most other shallow water invertebrates in having a protracted breeding season which often lasts for most of the year. According to Gordon (1932) the breeding season amongst subantarctic pycnogonids is from May to July and for Antarctic species, from October until April; the majority of the austral summer. These observations of N.hirtipes agree with the conclusions made by Gordon from the Antarctic species. For polar organisms to have a long breeding season is uncommon, it is usually strictly limited and closely synchronized with the plankton blooms of spring and early summer.

The external factors, if any, influencing the breeding season of N.hirtipes are unknown. Within the Arctic both temperature and salinity are stable throughout the year. The only factor that varies markedly being the day length.

Within N.hirtipes the sex ratio has been found to vary significantly as the summer progresses (Graph 4.4.1). During June and July the percentage of females is greater than males (A ratio of approximately three females to two males). As the summer progresses the number of males gradually increases until in September their number is equal to that of the females. The single December station consists of a majority of females, most of which appear to have only a small number of eggs within their ovaries. Of the males present the majority are in possession of maturing ovigeral egg masses and larvae.

The recruitment of the juveniles into the adult ranks may be responsible for the variation in the sex ratio. It is possible that

females mature during the winter months whilst the males remain as larvae until the following summer.

The only external difference between the last instar larva and an adult male is the state of the ventral femoral cement pores. In the larva these appear as a row of rounded nodules with no visible external pore, whilst in the adult each nodule is flat topped and bears a minute centrally placed pore. Samples of males examined for each of the months June to September show that the percentage of specimens bearing open glands increases as the summer progresses, indicating that the number of males being recruited from the juveniles is similarly increasing (Graph 4.4.2.).

The time-lag between the maturation of males and females may possibly be because oögenesis is more complex and lengthier than spermatogenesis. The females mature earlier so that sufficient ova will have been produced for the summer breeding season.

Hedgpeth (1963) states " that if these animals breed in summer, as the number of obviously undeveloped egg masses suggests, we would have to assume either that these pycnogonids grow to sub-adult size in a single season, or that they grow so slowly that the large young specimens being carried about have overwintered with their parents. Possibly hatching occurs in winter, as with the amphipod Themisto libellula (Dunbar, 1957)."

Therefore the life history of Nymphon hirtipes can be summarized as follows (Table 4.4.1) :-

After mating, the females die, leaving the males to overwinter with the maturing eggs. It can be assumed from the egg production thatthis species is polytelic. During the winter months the eggs

hatch and remain on the ovigers during the early stages of their post-embryonic development.

By the next summer the larvae have reached the sub-adult stage (fifth or sixth instar) and are lost from the male, which then dies. In laboratory conditions the larvae of N.hirtipes died soon after leaving the male without maturing beyond the subadult stage, (P.R.Richards, personal communication). This may indicate either that a further stage, perhaps involving a hydroid vector, may occur in the life cycle or that the available food was unsuitable for the developing larvae.

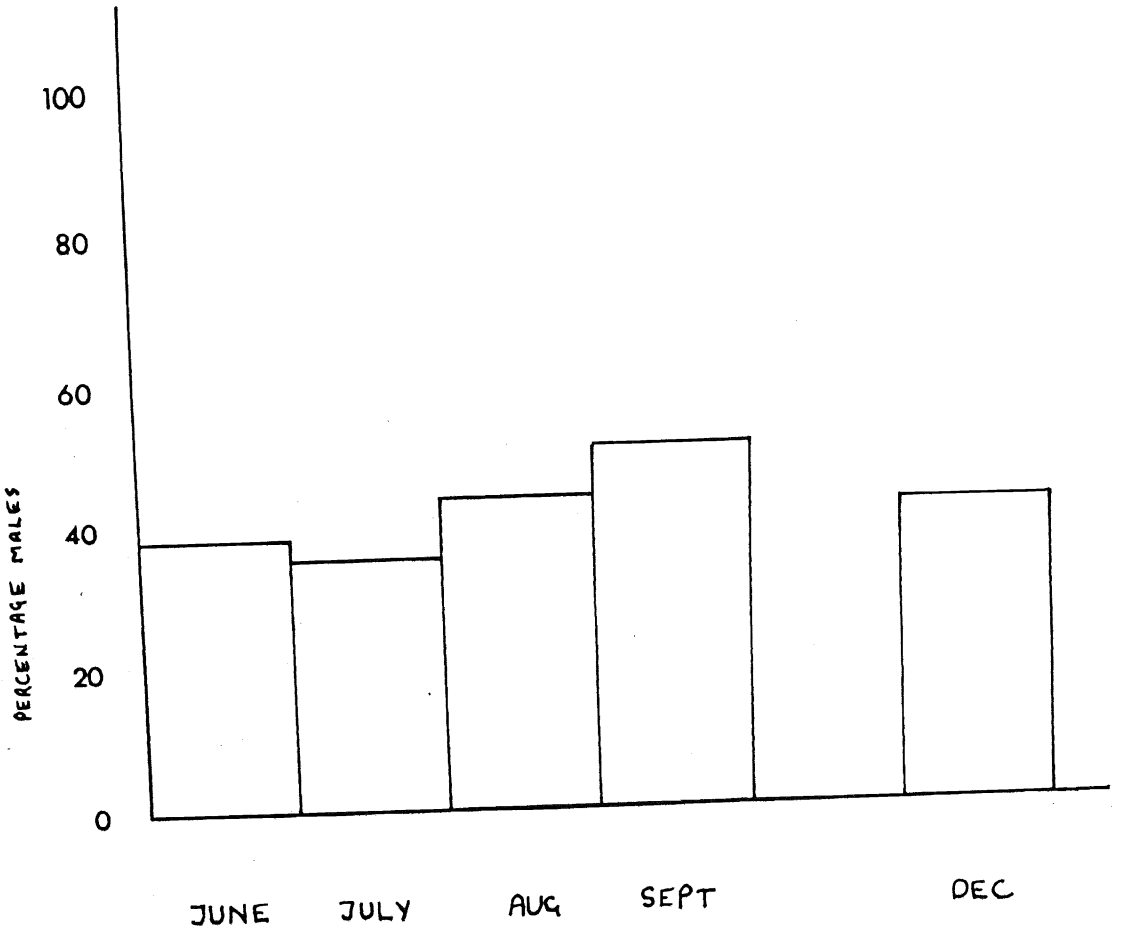
During the following winter the larvae continue to mature until, by the next summer, they have developed into juveniles half the size of the adults. At this stage they are sufficiently large to be collected in samples. Over the following winter the females reach maturity and begin to produce ova, whilst the males do not mature until the following summer when mating occurs and the cycle is repeated.

From oviposition to maturity for N.hirtipes therefore takes approximately two and a half years for females and three for males. When compared with the 150 days reported for Propallene longiceps (Nakamura, 1981) this is a comparatively long time. However, P.longiceps is a littoral sub-tropical species which has no protonymphon larval stage (this takes place within the egg before hatching) whereas N.hirtipes is a high arctic and deep water species. The difference in the environmental conditions between the two species must be responsible for the difference in developmental time.

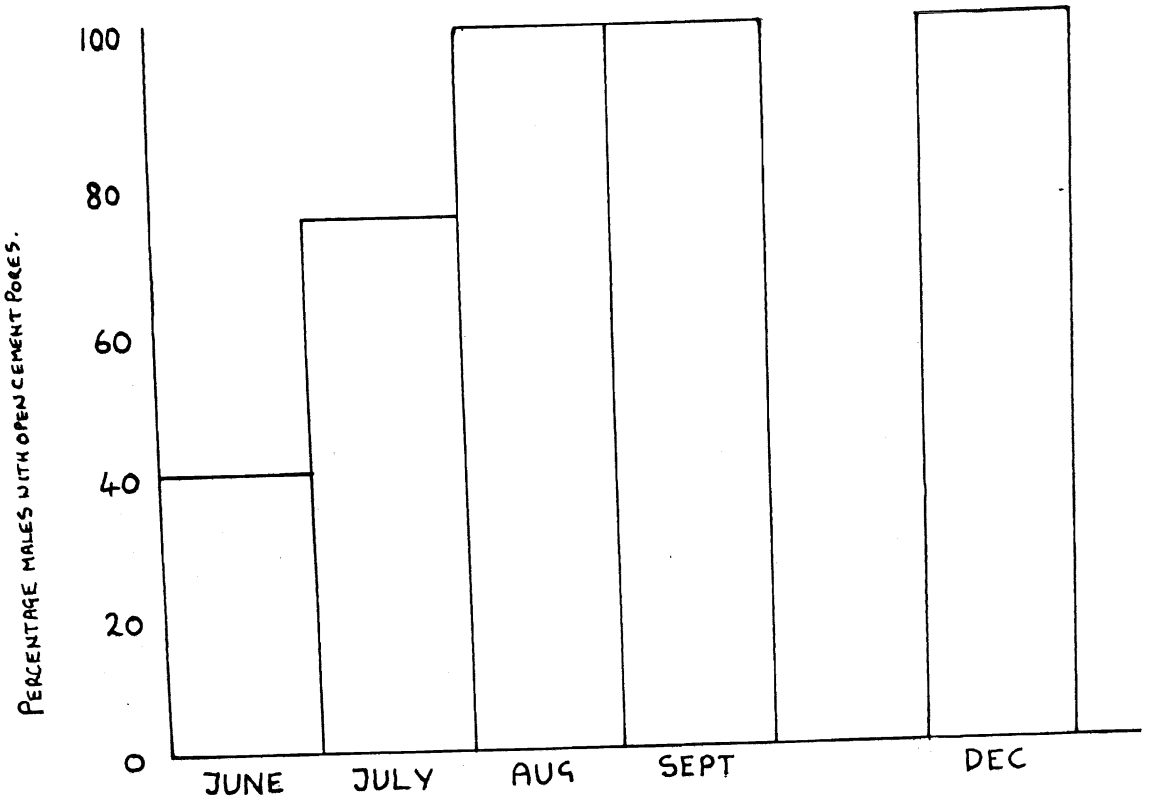
Table 4.4.1. Proposed life cycle for Nymphon hirtipes.

YEAR 1.	SUMMER	Mating occurs. Males receive fertilized eggs in balls on ovigers. Females die after mating.
	WINTER	Males overwinter with maturing eggs. Eggs hatch, early larval development takes place on male ovigers.
YEAR 2.	SUMMER	Larvae reach subadult stage and are lost from male. Male dies.
	WINTER	Larval development continues; site unknown. May be either free living or parasitic.
YEAR 3.	SUMMER	Juveniles attain size where they are caught in samples (approximately half adult size).
	WINTER	Female juveniles mature; oögenesis begins. Male juveniles continue development.
YEAR 4.	SUMMER	Male juveniles mature. Females in possession of of mature ova. Mating occurs.

GRAPH 4.4.1. POPULATION VARIATION IN MALE NYMPHON HIRTIPES.



GRAPH 4.4.2. VARIATION IN OPEN MALE CEMENT PORES.



5. SUMMARY.

1. As with some other ecological investigations, it proved necessary as a prelude to this work to clarify the nomenclatural complexities which has accumulated in the literature since Sars undertook the previous major revision of the genus in 1891. This has resulted in the recognition of 15 species of Nymphon in the Eastern Arctic. A key has been prepared for use in identifying them.

2. Two morphs which differ in size are evident in Nymphon hirtipes. The larger morph is the more numerous, the smaller occurs in only a few localities on the West Spitsbergen fishing banks. The two have never been found together and it may be, therefore, that the size difference is the result of environmental differences and is not of genetic origin.

3. Nymphon spinosissimum Norman 1908 has been incorporated into N. tenellum Sars 1888. As a result there are now two morphs within N. tenellum. The more abundant one is the robust form and the rarer one the graceful form. The robust form represents what was taken to be N.spinosissimum before its inclusion within N.tenellum. The two morphs are often found in the same locality, by contrast with the spatial separation of the two morphs of N.hirtipes.

4. The complexities surrounding the former genus Chaetonymphon (Sars 1891) have been rectified and discussed. Four species are now proposed, these are Nymphon hirtum, N.hirtipes, N.macronyx and N.tenellum.

5. Nymphon grossipes shows considerable morphological variation in the ratio of the length of the tarsus to that of the propodus. This led, in the past, to the fragmentation of the species. Biometric analyses now reveal that, with the exception of differences in the terminal segments of the walking legs, species such as N.glaciale, N.mixtum and N.piliferum resemble N.grossipes.

6. Detailed examination of the animals has revealed that the species of Nymphon under consideration fall into two groups with regard to the morphology of the legs. One group, exemplified by N.strömi, has long linear terminal leg segments which have reduced spination and poorly developed auxiliary claws. The other, exemplified by N.hirtipes, has shorter more robust terminal leg segments, long spines and well developed auxiliary claws. These interspecific differences give the N.strömi group a facility for a walking or striding movement and the N.hirtipes group a facility for clinging.

7. The long segments (4th, 5th & 6th) of the male ovigers of all fifteen species of Eastern Arctic Nymphon have been found to have several adaptations which increase their surface area compared with that of the females. These modifications, all of which afford a greater area for attachment of fertilized egg masses than would otherwise be the case, fall easily into five morphological groups which can be used as taxonomic features for distinguishing between the males of different species.

8. Both sexes of all fifteen species have been found to have a

gland-like structure of unknown function on the 4th ovigeral segment. A major histological and histochemical investigation is needed to ascertain both the detailed structure and possible function of the 'gland'.

9. The preliminary histological examination of the internal structure of the ventral cement glands of Nymphon hirtipes have shown that adult males in which the cement gland pores are open have a broad band of glandular tissue lying under the epidermis whereas specimens in the final larval stage lack these ventral pores and have little or no glandular tissue associated with this region.

A further, more detailed histological and histochemical investigation is needed to reveal the exact nature of the cement and the way in which it is elaborated.

10. The survey of cement pores in the males of Nymphon hirtipes and N. tenellum have shown that these structures can be used as taxonomic features. These two species are very similar, the major difference between them being that of maximum size of the adult. N. tenellum is much smaller than N. hirtipes when it is adult. In both species the number of pores increases with the size of the adult.

11. The size of the unfertilized ova in the ovaries and fertilized eggs on the male ovigers are similar within each species, but vary greatly between species.

There appear to be two reproductive strategies in the genus. In the first, which is typical of the striding forms such as N. strömi,

a large number of lightly yolked aggs are produced and the larvae spend only a short period of their post-embryonic development on the male ovigers before they disperse. The second group, which is typical of the clinging forms such as N.hirtipes, produces fewer, larger, heavily yolked eggs. The males overwinter with the larvae which are lost only when their metamorphosis is nearly complete.

12. The interspecific differences may well be indicative of differences in lifestyle associated with feeding and reproductive strategies. That such contrasts exist and may lead to various ways of surviving in the same habitat is consistent with the fact that a single lacality on the continental shelf in this region may support several species. Their differences presumably enable them to avoid direct competition by exploiting different facets of the same environment.

13. Existing data, together with the information made available by the present study, have made it possible to postulate a life-cycle for Nymphon hirtipes. This can only be a hypothesis as data cannot be obtained for a twelve month cycle owing to the adverse climatic conditions in the area during the winter months. It appears that N.hirtipes takes between two and a half and three years to attain maturity and breeds only during its last summer.

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APPENDIX I.

MATERIAL EXAMINED.

Abbreviations.

L.C.	Luton College of Higher Education.
BM(NH).	British Museum (Natural History). London.
ZIMA.	Zoological Institute Museum, Amsterdam.
ZIL	Zoological Institute, Leningrad.
M	Male.
F	Female.
J	Juvenile.

See Appendix II for Anton Dohrn and Walther Herwig station data.

Collection catalogue numbers are given in brackets.

MATERIAL EXAMINED.

Nymphon elegans.

L.C. WALTHER HERWIG. July / August 1979. 10 stations.
(16 = 2F 1J; 19 = 2M; 47F 24M 4J; 25 = 3F 2M 1J;
35 = 1M; 48 = 6F 4M; 72 = 1M; 137 = 4F 5M 2J;
139 = 1F 2M).

BM(NH). Spitsbergen. Sta 312,363. Norwegian North Atlantic expedition. G.O.Sars. From Christiana Museum. (90.12.1.6-15).

" Kara Sea. DIJMPHNA expedition. Syntype. Hansen,1876. (91.1.6.58).

" TRITON. Sta 9. 608 fms. Univ. Coll. Dundee. (1956.10.10).

" SILVER BELLE. Faroe Shetland Channel. (1908.3.11.2-4).

" Norman Collection. (1911.11.8).
49092-95 Faroe Channel. TRITON. Sta 9.
49096 Faroe Channel. PORCUPINE. Sta 57.

" Cape Ashton. 10.8.1893. Univ. Coll. Dundee. (1956.10.10. 381-82).

ZIMA 49.56 N 50.32 W. 320 metres. North Atlantic. 23.8.1969.

" T. Kjerstad. Determination, M.Weber.

Nymphon grossipes.

L.C. ANTON DOHRN. June / July 1978. 17 stations.
(75 = 1F 1M; 85 = 1F 2M 1J; 87 = 1F; 102 = 1F 2J;
105 = 1M; 106 = 2M; 110 = 1J 115 = 3F 6M; 116 = 1F 2J;
128 = 1F 1J; 138 = 1J; 141 = 1J; 143 = 7F 4M 3J; 144 =
2F 1M 1J; 147 = 2F 2M; 149 = 1F 1M; 150 = 1J).

L.C. WALTHER HERWIG.July/August 1979. 18 stations (24 = 1F 1J; 25 = 1M; 34 = 1F; 35 = 1J; 37 = 1M; 48 = 2J; 53 = 1M; 54 = 1F; 71 = 23F 9M 8J; 74 = 1M; 79 = 1F; 86 = 1M; 122 = 1F; 132 = 1F; 137 = 2F 5M 2J; 139 = 1F 1M; 143 = 1M; 155 = 1F).

" CIROLANA 1.12.1972. Sta 11/12. 60.21 N. 47.10 W, 140 metres.

" CIROLANA July 1978. various stations, North Sea.

BM(NH). Spitsbergen. Carl Island and Cape Torell. Rev A.E.Eaton. (74.15)

" Greenland. 40 - 50 metres. Mr Hobell. (53.68).

" Norway. Mr R. McAndrew. (55.95)

" Sukkertoppen. 44 fathoms. Mr Hobell's collection. (53.68).

" Stn 7. 10 miles N.E. of Griddleness. 60 fathoms. Muddy sand. Oct 1900. Univ Coll Dundee.(1956.10.10).

" Norway Norwegian expedition. (90.12.1.2-4).

" Franz Joseph Land. W.S.Bruce. 19.6.1897. 19 fathoms S.W. of Elmwood. (99.4.5.1-2).

" Franz Joseph Land. W.S.Bruce. 1.8.1897. 53 - 95 fms. (95.4.5.4).

" Orkney. July 1889. Univ Coll Dundee. (1956.10.10.386).

" Bell Island, Newfoundland, Labrador, Moray Firth. Univ Coll Dundee. (1956.10.10 387-391).

" Franz Joseph Land. W.S.Bruce. 8 fms. West Bay at Cape Flora. (99.4.5.5).

" Norman Collection (1911.11.8).
49001-2. Off Northumberland.
49003-4. Off Durham Coast.
49005. Off Northumberland.
49006-7. Firth of Forth 1884.
49008-10. Faroe Channel. Porcupine. 1869.
49011-12. Greenland. A.Hancock.
49013. N.E.USA. 1868.
49014-16. 60.14 N 6.14 W St 57 Porcupine, 1869.

" HMS CHALLENGER STA 49 (81.38).

ZIMA Norway.

" Spitsbergen, near Bear Island.Sta 1226. 14 fms. 24.8.1889.

" Spitsbergen, 1 mile off Bastian Eil.20 fms. 21.4.1889.

" Willem Barents,1874.

" North Sea. Aug 1913. J.Metzelaar.

ZIMA. Whales Back. Iceland. 70 fms.

ZIL White Sea.

Nymphon hirtipes.

L.C. Anton Dohrn. June/July 1978. 34 Stations. (73 = 1M; 74 = 1F 1M; 75 = 7F 9M; 77 = 1M; 85 = 1F 1M; 87 = 12F 3M 5J; 88 = 5F 4M 2J; 89 = 3F 1M 2J; 98 = 1F 1M 2J; 99 = 1F 1M; 102 = 1F; 105 = 1F; 106 = 38F 20M 3J; 107 = 230F 146M 15J; 108 = 14F 5M 2J; 110 = 16F 11M 5J; 114 = 2J; 116 = 4F; 117 = 27F 15M 2J; 126 = 1M 2J; 127 = 26F 16M 9F; 128 = 63F 81M 29J; 129 = 11F 8M 5J; 134 = 3F 1M; 135 = 2F 1M 4J; 138 = 1F 1M; 141= 2F 3M 1J; 142 = 9F 4M 5J; 143 = 1M 1J; 144 = 2M; 147 = 117F 127M 16J; 148 = 26F 22M 3J; 149 = 4F 10M; 150 = 2F 3M).

" Walther Herwig. July/August 1979. 39 stations. (14 = 1M; 15 = 2F 3M; 16 = 2F 1M 3J; 19 = 1M; 23 = 12F 10M 5J; 35 = 30F 24M 14J; 38 = 36F 24M 6J; 41 = 4F 4M 3J; 42 = 4F 3M 1J; 44 = 2F 8M 1J; 45 = 1M; 49 = 1F; 50 = 1M; 51 = 26F 32M 13J; 53 = 2F 1M; 54 = 3F; 55 = 6F 3M 3J; 59 = 1F 3M; 71 = 1M; 73 = 6F 4M; 74 = 95F 47M; 76 = 6F 3M; 78 = 9F 13M 3J; 79 = 42F 23M 10J; 80 = 2F; 82 = 5F 5M; 86 = 6F 8M 5J; 87 = 3F; 111 = 8F 12M 5J; 121 = 26F 15M 6J; 122 = 3F 3M; 130 = 1J; 131 = 13F 3M 4J; 132 = 10F 19M 8J; 133 = 1F 1M; 135 = 1F; 139 = 30F 27M 4J; 142 = 2F).

" Cirolana. 1.12.72. sta 11/12, 60.21 N 47.10 W. 140 metres.

" S.W. Iceland. 12.7.78. Sta 78. 64.46 N 12.32 W. 157 metres.
Sta 80. 64.30 N 12.59 W. 133 metres.

" Cirolana. 3.9.1975. Sta 86, 77.26 N 12.47 E. 188 metres.

BM(NH). Norman Collection. (1911.11.8). PORCUPINE. 1869.
49117. Voranger Fjord. E.Firmark.100-125 fms.
49118. Bog Fjord. E.Finmark. Sta 60. 120 fms.
49119-123. PORCUPINE Sta. 64,65,78,88.
49124-125. Off Halifax. 53 fms. USFC, 1877, Loc 118.

" Franz Joseph Land. W.S.Bruce. 21.7.1879. Between Cape Flora and Cape Gertrude. (99.4.5.7).

" Kara Sea. DIJMPHNA expedition. (91.1).

" KNIGHT ERRANT. Sta 8, 540 fms. 17.7.1880. (81.38).

" ERNERST HOLT. R.W.Blacker. 74.53 N 32.38 W. (2054).

BM(NH). M.V.ROSAURA. Sta 6 (3ft dredge) 110 metres. 7.9.1937.(71.266).

" Norman Collection. (1911.11.8). VALOROUS. 1875.175fms Off Greenland. (49114-116).

" Barents Sea, 1887. P.P.C.Hoek. Sta 87. 75.16 N 45.19 E. 30.7.1878. (81.39).

" North Norway, Jan Mayan, Spitsbergen. Norwegian North Atlantic Expedition. Sta 223,273,275,363. (90.12.1.37-43).

" Norman Collection. Mr Hodge. (1911.11.8/49107-08).

" ERNEST HOLT. Sta 36. North Atlantic. (1977: 229.5).

" Spitsbergen. Carl Island and Cape Torell. Rev. A.E.Eaton.(74.15).

" Off Bray Head, 15 fms. National Museum, Iceland.(1921.5.27.13).

" Spitsbergen. Rev. A.E.Eaton.(74.15).

" ERNEST HOLT. Voyage 3/54. 17.51954. Sta 80. (1977:230.2).

" Discovery Bay. 25 fms. Capt. A.W.Fielden. (77.19).

" Franz Joseph Land. B.L.Smith. (80.32).

" Winter quarters of HMS ALERT. 82.27 N. (78.14).

" Off Halifax, Nova Scotia. 52 fms. 1877. (80.29).

" Discovery Bay. Arctic expedition. 30 fms. (78.15).

" Franklin, Pierce Bay. 15 fms. Capt Fielden. (77.19).

" Floety? Capt Fielden. (77.19).

" STELLA CARINA. Aug 1939. G.J.Lockley. Barents Sea.

" Fuchs and Bartmann collection. Norwegian Sea. 1935-6.

ZIMA. E.Spitsbergen. 1 mile off Bear Island. 15 fms.

" Spitsbergen. 1.5 miles N.W of Rky-ys-eil, 65 fms. 23.6.1889.

" N.Atlantic. 63.10 N 53.40 W.1097 metres. 14.9.1969.

" Autour. 66.20 N 12.28 W. 180-220 metres. 21.6.1938. Belgian National Museum.

" N.Atlantic. 49.56 N 50.32 W. 320 metres. 23.8.1969.

Nymphon hirtum.

L.C. CIRCLANA. July. 1978. Northern North Sea 1 male.

BM(NH). Norman Collection. (1911.11.8)
49140 Montrose
49141 Firth of Forth. Sta 111: 1887.

BM(NH). Sound of Mull. Rev. J.S.Way.

ZIMA. Noordelijk, Deel. Whitby. 5 miles off Coast. 20.9.1957.

Nymphon leptocheles.

BM(NH). Norman Collection. (1911.11.8).
49045-48. Trondheim Fjord. 150-200 fms. 1893.
49050-52. Kors Fjord. Norway.
49053-55. Norway, 1879. Sta 36,44.
49056-58. Norway, 54,55, 45-70 metres.
49062. PORCUPINE. Sta 47. 1869.

ZIMA. NORBI. sta. CP 11. 69.52 N 17.08 W. 300 metres. 28.7.1975.

ZIL. White Sea.

Nymphon longimanum.

ZIMA. E.Spitsbergen. Karl Island. 45 fms. 12.8.1889. (Pa 1221).

" Varna Expedition. 1883.

ZIL. White Sea.

Nymphon longitarse.

BM(NH). Spitsbergen. Sta 336. Norwegian North Atlantic Expedtition. G.O.Sars. (90.12.1.16).

" Norman Collection. (1911.11.8).
49026-7 Vadso Bank. Firmark. 1890.
49028 Mass Bay. 35 fms. North USA.

" Fuchs and Bartmann Collection. Norwegian Sea. 1935-6.

ZIMA. VARNA expedition. 1883.

ZIL. White Sea.

Nymphon macronyx.

BM(NH). Franz Joseph Land. W.S.Bruce. 8.7.1897. 77.55 N 55.25 E. 115 fms. (99.4.5.8).

" TRITON. Sta 9. 608 fms. Univ Coll Dundee. (1956.10.10.363-370).

" INGOLF expedition. Sta 101-108. Univ Coll Dundee (1956.10.10. 393-396).

" Norman Collection. (1911.11.8)
49142-151. PORCUPINE Sta 57. 632 fms.
49152-156. TRITON. Sta 11. 555 fms.
49157-178. TRITON. Sta 9. 608 fms.

BM(NH). Kara Sea. DIJMPHNA expedition.(91.1).

" SILVER BELLE. Faroe Shetland Channel. Sta 3, 507 fms. 60.46 N 3.36 W. (1908. 3.11.11-16).

" Spitsbergen. Sta 362. Norwegian North Atlantic Expedition. G.O.Sars. (90.12.144-156).

" TRITON. Sta 9, 608 fms. (98.7.7.1-20).

" KNIGHT ERRANT. Sta 11. 17.8.1880. 540 fms. (81.38).

ZIMA. VARNA Expedition, 1883.

" Willem Barents Expedition, 1880-84.

" E.Spitsbergen. 6.5 miles off Walter Thymen strait. 40 fms.

ZIL. White Sea.

Nymphon macrum.

L.C. ANTON DCHRN. June/July 1978. 2 stations. (116 = 1F 2M; 127 = 1M.).

" WALTHER HERWIG. July/August 1979. 1 Station. (34 = 1M).

BM(NH). TRITON. sta 10.(98.7.8.106-112).

" Norway. Sta 290. Norwegian North Atlantic Expedition. G.O.Sars. (90.12.1.1).

" Norman Collection. (1911.11.8).

49097-101	Trondheim Fjord 150-200 metres.
49102	Gulf of Maine USA. 110 fms.
49103	TRITON. 1882. Sta 11.

" Davis strait. Sta 10. 59.40 N 7.21 W. 516 fms.24.8.1882. (1956.10.10.397).

ZIMA. TRITON. Sta 10.

" VARNA expedition, 1883.

Nymphon megalops

L.C. ANTON DCHRN. June/July 1978. 12 stations. (85 = 4F 1M; 113 = 1J; 115 = 1F 3M; 117 = 2M; 125 = 1F; 126 = 2F; 127 = 2F 2M; 128 = 4F 1M; 135 = 1F 1M; 142 = 1F 1J; 144 = 2F 2M; 150 = 1M).

" CIROLANA. 1.12.1972. Sta 11/12. 60.21 N 47.10 W. 140 metres.

" CIROLANA. 3.9.1975. Sta 86. 77.26 N 12.47 E. 188 metres.

BM(NH). Norman Collection. Type, Norwegian North Atlantic Expedition. Sta 48. G.O.Sars. (1911.11.8/49105).

" SILVER BELLE. Faroe Shetland Channel. Sta 3. 60.41 N 3.36 W. 507 fms. 13.7.1907. (1908.3.11.1).

" INGOLF expedition. 61.23 N 5.00 W. (1956.10.10.398).

" Spitsbergen. Sta 343. Norwegian North Atlantic Expedition. G.O.Sars. (90.12.1.5).

Nymphon microrhynchum.

ZIMA. E.Spitsbergen. Deevie Bay by Barentine Eil. 13-15 metres. 22.8.1889 (Pa).

Nymphon serratum.

L.C. ANTON DOHRN. June/July 1978. 13 stations. (75 = 1F; 88 = 2F 1M; 91 = 1F; 98 = 1M; 99 = 1J; 102 = 1F 2M; 106 = 3F 1M 3J; 107 = 1F; 127 = 1F; 135 = 1F; 142 = 1F 1M 1J; 143 = 2F 1M; 147 = 1M).

" WALTHER HERWIG. July/August 1978. 18 stations. (34 = 1M; 35 = 2F 1M; 42 = 1F; 51 = 2F 1M; 53 = 1M; 54 = 1M; 55 = 6F 2M; 58 = 1F; 74 = 1M; 78 = 1M; 79 = 1F 1M; 86 = 2M; 111 = 3F; 117 = 1F 1M; 122 = 1F 4M; 132 = 4F 2M; 139 = 1F 1M; 143 = 2F).

" CIROLANA. 1.12.1972. Sta 11/12. 140 metres.

" CIROLANA. 3.9.1975. Sta 86. 188 metres.

BM(NH). Spitsbergen. Carl Island and Cape Torell. Rev. A.E.Eaton. (74.15?).

" Norman Collection. VALOROUS. Greenland 1874. 175 metres. (1911.11.8/49104).

" STELLA CARINA. Aug 1939. G.J.Lockley. Barents Sea off Bear Island.

" Fuchs and Bartmann Collection. Norwegian Sea. Easter 1936. 250 fms. S.W. of Bear Island.

ZIMA. W.Spitsbergen. Deevie Bay. By Whale point. 9.4.1889.

" Whales Back, Iceland. 70 fms.

" Willen Barents expedition. 1879-83.

Nymphon sluiteri.

L.C. ANTON DOHRN. June/July 1978. 2 stations. (87 = 1F 5M; 107 = 1M).

" WALTHER HERWIG. July/August 1979. 1 station. (35 = 1M).

" CIROLANA. 3.9.1975. 77.26 N 12.47 E. 188 fms.

BM(NH). Davis strait. Univ, Coll. Dundee. (1956.10.10.?).

" Kara Sea. DIJMPHNA expedition. (91.1).

" Norman Collection. Kara Sea. DIJMPHNA expedition. Copenhagen Museum. (1911.11.8/49056-66).

" Fuchs and Bartmann collection. Discovery Bay, off Grincids?. 30 fms. 1878.

ZIMA. Willem Barents and VARNA expedition, 1878.

" W. Spitsbergen.

" E.Spitsbergen. Walter Thymen strait. 6.9.1889.

Nymphon strömi

L.C. ANTON DOHRN. June/July 1978. 44 stations. (73 = 1J; 74 = 7F 11M; 75 = 4F 3M; 85 = 10F 6M 6J; 87 = 3F 5M 2J; 88 = 39F 37M 9J;89 = 9F 9M 3J; 91 = 1F 1M 2J; 98 = 18F 12M 1J 99 = 2F 2M; 100 = 1F; 101 = 1F; 102 = 48F 52M 9J; 103 = 5F 4M 4J; 105 = 3F 3M 5J; 106 = 28F 25M 9J; 107 = 18F 8M 4J; 108 = 1M; 110 = 7F 3M 1J; 111 = 2F 7M 2J; 112 = 3F 5M 5J; 113 = 1F 3M; 114 = 1F 5M; 115 = 7F 5M 3J; 116 = 14F 14M 6J; 117 = 8F 12M 4J; 124 = 7F 6M 1J; 125 = 4F 5M 1J; 126 = 4F 11M 2J; 127 = 20F 18M 20J; 128 = 63F 81M 29J; 129 = 40F 31M 11J; 134 = 3F 3M; 135 = 2F 4M; 136 = 1M; 138 = 4M; 141 = 17F 22M 7J; 142 = 5F 7M 3F; 143 = 7F 11M 8J; 144 = 5F 7M 3J; 147 = 3F 1M 3J; 148 = 11F 12M 4J; 149 = 5F 2M 1J; 150 = 3F 4M 1J).

" WALTHER HERWIG. July/August 1979. 48 stations. (13 = 1M; 14 = 1M; 15 = 2F 2M; 21 = 10F 9M 5J; 13 = 1M; 24 = 1F; 25 = 1F 3M 2J; 34 = 4F 4M 1J; 35 = 25F 24M; 37 = 11F 13M 5J; 38 = 13F 15M; 41 = 12F 18M 6J; 42 = 1M; 44 = 1F 3M; 45 = 2F 3M; 48 = 16F 20M 6J; 49 = 1F 3M; 50 = 1M; 51 = 20F 18M 3J; 53 = 4F 2M; 54 = 4F 4M 4J; 55 = 1M; 57 = 10F 6M; 58 = 1F 2M; 59 = 1J; 71 = 10F 16M 2J; 72 = 1M; 73 = 14F 7M 1J; 74 = 28F 20M 6J; 76 = 3F 5M; 78 = 28F 15M 9J;

79 = 43F 47M 2J; 80 = 4F 3M; 82 = 6F 2M; 86 = 23F 45M 7J; 87 = 2F 1M; 111 = 4F 2M; 121 = 3F 7M; 122 = 27F 19M 3J; 130 = 1F 3M; 132 = 20F 26M 5J; 133 = 3F 2M 2J; 135 = 6F 14M 3J; 138 = 49F 48M 7J; 139 = 12F 13M 3J; 142 = 4F 5M 1J; 143 = 1F).

CIROLANA. 1.12.1972. Sta 11/12. 60.21 N 47.10 W. 144 metres.

CIROLANA. 3.9.1975. Sta 86. 77.26 N 12.47 E. 188 metres.

CIROLANA. July 1978. Northern North Sea.

CIROLANA. July 1979. Northern North Sea.

12.7.1978. S.W. Iceland. Sta 79. 64.46 N 12.32 W. 157 metres.
Sta 80. 64.30 N 12.59 W. 133 metres.

Barents Sea, 1879. Presented by P.P.C.Hoek. (81.39)

Discovery Bay, off Grinoids. 30 fms. (71.85).

81.50 N. Collected by W. Fielden. (77.19).

Tloeboug Beach ? 1876. 10 fms. Collected by Capt. Fielden.(77.19).

Norman Collection. Trondheim Fjord. 1893.(98.7.7.41-43).

Sumberg Head, 1900. Univ. Coll. Dundee. (1956.10.10.403-4).

TRITON. Sta 8. (98.7.8.101-5).

Norman Collection. Lang Fjord. W.Denmark, 1890.(1911.11.8/49286).

Capt. Fraser, 80 fms. Collected by Capt. Fielden. (77.19).

Entrance to British Channel ? (59.4.15.34?).

KNIGHT ERRANT. Sta 8.

Norman Collection. (1911.11.8).

49067-69	Hardanger Fjord. Sta 68,71.
49070	Servig, Norway. 25 fms. 1879
49071-74	Norway, 1878.
49079	NNE of Shetlands PORCUPINE. sta 66.
49080-81	Hardanger Fjord, Norway. Sta 30,31.
49082	N.E.USA. (Wilson) USFC? Loc 127.
49088-91	Trondheim Fjord, Norway, 1893.

Kara Sea. DIJMPHNA expedition. (91.1).

Sta 223. Norwegian North Atlantic Expedition. Original label = Nymphon helleri, renamed according to Schimkewitsch, 1930. (90.12.1.17-22).

STELLA CARINA. Aug 1939. G.J.Lockley. Barents Sea, off Bear Island. 50-150 fms.

BM(NH). Fuchs and Bartmann collection. S.W. of Bear Island. Easter, 1936. 250 fms.

ZIMA. Willem Barents Expedition. 1878-84. 69-77N, 23-56E. All stations.

" 58.14 N 3.20 E. April 1936.

" VARNA expedition, 1883.

" Onbekende Vindplaats.

" Nordsee of Atlantic Ocean, off Iceland, 1929.

" 66.20 N 12.28 W. 20-24 fms. May 1938.

" GERDA. Sta 311. 25.41 N 79.31 W.805-787 metres. 24.5.1964.

" GERDA. Sta 354. 25.39 N 79.32 W. 805-830 metres. 24.8.1964.

" GERDA. Sta 170. 27.06 N 79.36 W. 677-659 metres. 29.6.1963.

" Nordsee. Aangevoerd het ijmuider trawlers. Apr 1951.

Nymphon tenellum.

L.C. ANTON DOHRN. June/July 1978. 7 stations. (114 = 1J; 115 = 1F 1M; 126 = 4F 10M 1J; 135 = 2M; 141 = 1F 1M; 143 = 7F 4M 3J; 144 = 6F 6M 2J).

" WALTHER HERWIG. July/August 1979. 6 stations. (9 = 1F 2M; 21 = 1M; 24 = 2F 1M; 71 = 6F 5M; 78 = 1F; 137 = 2F).

" CIROLANA. 1.12.1972. Sta 11/12. 60.21 N 47.10 W. 140 metres.

BM(NH). Norman Collection. (1911.11.8).

49126	Albatross sta 2488.
49127-31	Trondheim Fjord. 1893.
49132-35	Hardanger Fjord, 1879. 120-190 fms.
49136-39	PORCUPINE. Sta 78,88.

" STELLA CARINA. Aug 1939. G.J.Lockley. Barents Sea, off Bear Island.

" Fuchs and Bartmann Collection. S.W.Bear Island. Easter 1936. 250 fms.

ZIMA Willem Barents expedition. 1878-84.

APPENDIX II.

EASTERN ARCTIC NYMPHON STATION RECORDS.

A. *N.elegans* Hansen, 1887.

B. *N.grossipes* Fabricius, 1794.

C. *N.hirtipes* Bell, 1853.

D. *N.hirtum* Fabricius, 1794.

E. *N.leptocheles* Sars, 1891.

F. *N.longimanum* Sars, 1891.

G. *N.longitarse* Krøyer, 1844.

H. *N.macronyx* Sars, 1877.

I. *N.macrum* Wilson, 1878.

J. *N.megalops* Sars, 1877

K. *N.microrhynchum*. Sars, 1891

L. *N.serratum* Sars, 1877.

M. *N.sluiteri* Hoek, 1881.

N. *N.strömi* Krøyer, 1844.

O. *N.tenellum* Sars, 1888.

H.M.S. PORCUPINE (1869). (Norman, 1908).

STATION.	DATE.	POSITION. LAT.	POSITION. LONG.	DEPTH. (M)	SPECIES.
47	8.69	59.34N	7.18W	991	E.
51	8.69	60.06N	8.14W	804	O.
55	8.69	60.04N	6.19W	1106	A.
57	8.69	60.14N	6.17W	1155	B.
64	25.8.69	61.29N	3.44W	1170	C.
65	26.8.69	61.10N	2.21W	631	C.
66.	26.8.69	61.15N	1.44W	488	N.
78	1.9.69	60.14N	4.30W	530	C,O.
88	6.9.69	59.26N	8.23W	1289	C,O.

NORWEGIAN NORTH ATLANTIC EXPEDITION (1876-8). (Sars, 1891).

STATION.	DATE.	POSITION. LAT.	POSITION. LONG.	DEPTH. (M)	SPECIES.
18	26.6.76	62.44N	1.48E	753	A,H.
31	29.6.76	63.10N	5.00E	762	A,B,J.
48	8.8.76	64.36N	10.22W	547	A,C,J.
124	5.6.77	66.41N	6.59E	640	A,H.
137	21.6.77	67.24N	8.56E	826	H.
164	21.6.77	68.21N	10.40E	835	A.
190	7.7.77	69.41N	15.51E	1590	H.
192	7.7.77	69.46N	16.15E	1186	H.
200	17.7.77	71.25N	15.41E	1133	J.
223	1.8.77	70.45N	8.24E	128	B,C,N.
262	26.7.78	70.36N	32.35E	271	A,C,H.
267	29.6.78	71.42N	37.01E	271	C.
270	30.6.78	72.47N	35.01E	249	C.
273	1.7.78	73.25N	31.30E	360	B,C.
275	2.7.78	74.08N	31.12E	269	A,C.
286	6.7.78	72.57N	14.32E	817	H.
290	7.7.78	72.27N	20.51E	349	B,C,E,I,M.
312	22.7.78	74.54N	14.53E	1230	A.
315	22.7.78	74.53N	15.55E	392	A,L.
326	3.8.78	75.31N	17.50E	225	C.
336	5.8.78	76.19N	15.42E	128	C,G.
338	6.8.78	76.19N	18.01E	267	C,L.

NORWEGIAN NORTH ATLANTIC EXPEDITION, (Continued).

STATION.	DATE.	POSITION. LAT	LONG	DEPTH. (M)	SPECIES.
343	7.8.78	76.34N	12.57E	1358	C,H,J.
362	14.8.78	72.59N	5.40E	839	H,N.
363	14.8.78	80.03N	8.28E	475	A,C,N.

WILLIAM BARENTS (1878-9). (Hoek,1881).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
3	15.7.78	74.20N	18.30E	46	B.
6	25.7.78	72.05N	37.57E	292	C.
8	29.7.78	74.09N	42.02E	292	C,N.
9	30.7.78	75.16N	45.19E	183	C,M,N,O.
11	1.8.78	77.00N	45.48E	201	N.
13	13.8.78	73.00N	43.00E	219	C.
14	23.8.78	73.25N	55.00E	18	B.
5	14.7.79	72.32N	36.39E	234	C.
7	19.7.79	75.23N	38.39E	161	C.
8	21.7.79	76.05N	42.08E	274	C,N.
10	24.7.79	73.42N	43.38E	265	C.
12	30.7.79	71.06N	50.20E	113	C.
13	31.7.79	71.23N	49.38E	122	B,C,G.
14	13.8.79	73.10N	57.00E	11	G.

H.M.S. KNIGHT ERRANT (1880). (Hoek, 1881).

STATION.	DATE.	POSITION. LAT.	LONG	DEPTH. (M)	SPECIES.
5	11.8.80	59.26N	7.19W	941	N.
7	11.8.80	59.36N	7.18W	969	N.
8	17.8.80	60.03N	5.51W	987	B,H,N.

H.M.S. TRITON (1882). (Hoek, 1883).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
5	1882	60.12N	8.15W	810	C.
6	1882	60.09N	8.17W	815	B,H,N.
8	1882	60.18N	6.15W	1170	H,N.
9	23.8.82	60.05N	6.21W	1111	A,B,H,N.
10	1882	59.40N	7.21W	943	B,H,I.
11	1882	59.39N	7.13W	1015	E,H,I.

PRINCESS ALICE (1898). (Bouvier, 1917).

STATION.	DATE.	POSITION. LAT	LONG	DEPTH. (M)	SPECIES.
922	6.7.98	58.16N	5.48W	343	O.
960	29.7.98	72.37N	20.00W	394	C.
966	30.7.98	Bareen Island		20	B.
970	31.7.98	76.30N	25.27W	48	B,L.
997	11.8.98	78.73N	17.10W	102	C.
1012	18.8.98	80.01N	10.15W	430	C,M,N,O.
1020	20.8.98	78.08N	13.44W	393	C,N.
1043	13.9.98	59.03N	1.47W	88	B.

VALDIVIA (1898). (Möbius, 1901).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
7	7.8.98	60.37N	8.47W	588	C,I.
10	7.8.98	59.37N	8.50W	1326	H.

BRUCE ON BLENCATHRA (1898). (Carpenter, 1902).

STATION	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1	6.6.98	70.52N	49.10E	62	B.
2	16.6.98	70.48N	53.09E	37	B.
3	13.7.98	76.28N	33.06E	183	H.
4	15.7.98	78.21N	27.55E	183	N.

DANISH INGOLF EXPEDITION. (Meinert, 1899).

STATION.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
2	60.04N	9.22W	493	B,H,N.
3	63.35N	10.24W	511	N.
4	64.07N	11.12W	446	C,H.N.
7	63.17N	15.41W	1128	E.
9	64.18N	27.00W	555	C.
15	66.18N	25.29W	620	A,C.
44	61.42N	9.36W	1025	N.
51	64.15N	14.22W	128	C.
53	63.15N	15.07W	1495	C.
54	63.08N	15.40W	1299	C.
78	60.37N	27.52W	1502	C.
87	65.02N	23.57W	207	B,C,N.
91	61.44N	27.00W	912	I.
93	64.24N	35.14W	1143	C,J,L.
94	64.56N	36.19W	384	L.
95	65.14N	30.39W	1414	B.
98	65.38N	26.27W	259	C.
101	66.23N	12.05W	1010	H.
103	66.23N	8.52W	1089	H.
105	65.34N	7.81W	1434	H,M.
106	65.34N	8.54W	840	M,N.
116	70.05N	8.26W	697	A,H.
126	67.19N	15.52W	551	A.
127	66.33N	20.05W	83	B,C,L.
138	63.26N	7.56W	885	A,E,J,M.
139	63.36N	7.30W	1320	H.
140	63.29N	6.59W	1466	H.
141	63.22N	6.58W	1277	H.
144	62.49N	7.12W	519	C,J.

SWEDISH ZOOLOGICAL EXPEDITION (1899-1900). (Lönnberg, 1902).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
24	1899	73.24N	21.25W	70	C.
41	1899	72.43N	24.49W	50	C.
6	1900	Spitsbergen		350	C.
7	1900	78.20N	11.30E	7	B.
16	1900	72.25N	17.56W	300	A,C.
18	1900	74.30N	18.40W	90	B,C.
19	1900	74.35N	18.15W	150	C,N.
20	1900	73.55N	19.20W	150	B,C,N.

MICHAEL SARS (1900-14). (Stephensen, various papers. Ammended by J.W.Hedgpeth, 1948).

STATION.	DATE	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
62	5.9.1900	74.19N	16.30W	280	I,N.
II	9.5.01	71.22N	27.55W	393	E.
37	29.6.02	62.42N	1.26E	775	A.
38	29.6.02	62.33N	1.56E	550	C.
55	19.7.02	62.40N	1.56E	670	A.
56	20.7.02	62.23N	2.03E	500	N.
67	28.7.02	62.35N	4.04W	600	A.
75	10.8.02	60.10N	6.35W	1220	A.
76	11.8.02	59.28N	8.01W	1200	H,O.
91	23.8.02	64.27N	13.27W	160	B,C,I,L,N,O.
144	1.7.03	58.00N	3.24E	93	N.
212	19.6.04	57.44N	5.35E	100	N.
275	6.7.04	51.09N	1.30W	96	N.
108	1909	70.32N	18.17E	300	E.
6	4.6.14	70.09N	30.52E	200	C.
7	5.6.14	70.18N	32.23E	206	L.
28	24.6.14	70.16N	32.20E	220	C.
62	16.7.14	75.15N	20.36E	180	C.
63	16.7.14	74.09N	19.18E	106	C.
65	18.7.14	74.15N	17.15E	175	E,L.

BELGICA (1905). (Unpublished).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
4	19.6.05	79.51N	11.37E	80	B,C.
11a	7.7.05	79.52N	10.42E	310	C,L.
32	24.7.05	79.58N	14.10W	300	H.
41	31.7.05	78.09N	14.01W	78	B,C.
45	3.8.05	77.31N	18.24W	-	A,N.

SILVER BELLE (1908). (Unpublished).

STATION.	DATE.	POSITION LAT.	LONG.	DEPTH. (M)	SPECIES.
3	13.7.07	60.41N	3.36W	927	H,J.
9	18.7.07	60.40N	5.47W	905	A.
10	19.7.07	60.30N	6.24W	908	A.

POURQUOI PAS. (1913). (Bouvier,1914).

STATION.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
22	70.47N	8.02W	140	C,F.
25	71.04N	7.56W	70	C.
27	70.58N	8.07W	160	C,N.
28	70.58N	8.42W	40	B,C.
29	70.56N	8.55W	40	C.
31	66.13N	23.42W	50	C.
32	66.00N	24.14W	60	D.

BARTLETT COLLECTION (1926-41). (Hedgpeth, 1943).

DATE.	POSITION.		DEPTH.	SPECIES.
23.6.27	70.00N	33.17E	122	E,L.
29.7.31	74.21N	16.30W	75	C.
30.7.31	74.04N	17.58W	120	C.

ICELAND. (Stephensen, 1937. Zoology of Iceland)

POSITION.		DEPTH.	SPECIES.
LAT.	LONG.	(M)	
64.51N	13.44W	150	C.
65.42N	13.57W	113	L.
65.14N	14.08W	51	O.
64.00N	14.22W	128	O.
64.04N	15.42W	65	B.
66.17N	18.14W	98	C.
63.27N	18.27W	150	O.
63.20N	20.00W	70	D.
63.15N	20.04W	216	O.
63.33N	20.05W	83	B,C.
63.30N	20.14W	80	B,D,G,N.
63.18N	21.30W	178	B,E,O.
63.15N	22.23W	276	B,E,N,O.
64.04N	22.26W	40	D.
66.13N	23.42W	50	D.
65.02N	23.56W	207	B,N,O.
65.52N	23.58W	62	D.
66.00N	24.14W	60	D.
66.08N	24.12W	90	C.
66.53N	24.42W	215	B,C,N.
66.13N	25.10W	-	E.
66.20N	25.12W	175	C,I.

ERNEST HOLT. (1949-53). (Blacker, 1957).

CRUISE & STATION	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1949(IV)				
13	74.00N	17.56E	174	N.
1949(V)				
9	74.28N	16.25E	311	N.
25	74.15N	16.29E	283	N.
32	74.36N	16.52E	182	B,N.
34	74.30N	16.34E	274	B,I.
39	74.44N	17.45E	201	C.
70	73.54N	19.25E	345	N.
72	73.54N	19.50E	177	C,N.

ERNEST HOLT. (Continued).

CRUISE & STATION.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1949(VII)				
60	75.03N	25.37E	182	C,L.
61	75.01N	25.47E	208	N.
1949(VIII)				
19	76.51N	32.00E	135	N.
1949(IX)				
9	74.31N	17.04E	117	B,L.
16	74.36N	16.40E	210	C,N.
17	74.28N	16.42E	200	C,N.
21	73.58N	17.40E	216	C,I.
29	74.21N	17.42E	148	C,M,N.
31	74.13N	17.19E	188	C.
1950(I)				
81	74.21N	20.40E	201	C.
1950(II)				
44	73.55N	18.56E	457	C.
1950(V)				
11	74.31N	17.28E	137	B,C,L.
12	74.38N	17.14E	157	B,C,L.
27	74.40N	16.36E	219	N.
33	74.24N	17.20E	182	C,K,L,N.
38	74.13N	16.38E	274	N.
44	74.45N	17.07E	377	L.
50	70.02N	17.36E	212	A,B,I,L,N.
52	74.03N	17.54E	216	B,C,I,L,M,N.
54	74.10N	17.52E	181	B,C,N.
57	74.09N	18.04E	146	C,L,N.
59	74.04N	17.06E	238	B.
62	74.08N	16.26E	329	I.
68	74.43N	17.02E	229	K.
72	74.38N	17.36E	124	B,C,L.
76	74.45N	17.23E	256	N.

ERNEST HOLT. (Continued).

CRUISE & STATION	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1950(VII)				
49	74.39N	17.22E	143	C,N.
50	74.39N	17.40E	146	C,N.
52	74.33N	17.03E	165	C.
53	74.37N	17.25E	135	C.
54	74.33N	17.26E	143	B,C,L.
56	74.45N	18.26E	165	B.
57	74.44N	18.02E	182	B,N.
59	74.45N	18.45E	150	C,L.
72	74.26N	20.20E	119	G.
80	74.01N	18.40E	137	C.
88	74.38N	18.20E	143	C.
101	74.56N	18.30E	194	C.
102	75.03N	17.25E	179	N.
1950(VIII)				
43	73.40N	18.32E	238	N.
44	73.43N	18.34E	292	N.
54	73.59N	19.06E	133	C.
1950(IX)				
41	74.34N	17.45E	113	C.
42	74.30N	17.30E	139	C,L.
57	74.40N	18.29E	95	B,C,L.
91	74.26N	17.16E	175	C,M.
92	74.25N	18.02E	124	B,C.
131	73.55N	18.08E	201	N.
1951(II)				
8	74.22N	23.45E	247	C,N.
11	74.10N	23.11E	307	C.
22	73.52N	17.58E	219	C,N.
1951(III)				
40	74.12N	22.31E	271	C,N.
42	74.15N	23.10E	212	C,N.
43	74.45N	25.22E	292	C.
46	74.38N	25.45E	329	C.
59	74.16N	32.45E	265	C,N.

ERNEST HOLT. (Continued).

CRUISE & STATION	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1951(III) cont.				
60	74.16N	32.41E	247	C,L,N.
64	73.05N	33.50E	223	L.
1951(IV)				
20	74.07N	16.27E	292	N.
21	74.06N	16.50E	238	N.
22	73.59N	18.53E	128	B,L.
23	73.57N	19.18E	141	B,C,L.
24	74.17N	22.42E	192	C,N.
25	74.20N	23.05E	274	C,N.
26	74.37N	26.06E	311	B,C.
28	75.31N	26.40E	201	B,C,L,N.
32	75.47N	30.40E	322	C,M.
36	75.20N	33.32E	165	B,C,L,M,N.
41	75.52N	34.50E	194	B,C,M,N.
44	75.08N	30.35E	375	C,N.
47	75.09N	26.30E	219	C,N.
50	75.06N	24.30E	165	C,N.
51	75.00N	24.30E	168	N.
52	74.27N	23.25E	186	C.
53	74.23N	23.17E	153	C.
54	74.17N	23.20E	210	B,C.
55	74.18N	23.20E	238	C,L,N.
56	74.13N	23.25E	311	C,N.
1951(V)				
110	74.14N	16.36E	174	C.
1951(VI)				
35	74.37N	17.18E	156	C,L.
44	76.31N	14.34E	219	C.
63	77.09N	12.15E	201	C,N.
1952(I)				
27	74.31N	17.30E	135	L.

ERNEST HOLT. (Continued).

CRUISE & STATION	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1952(III)				
44	71.10N	28.32E	269	I,O.
46	74.08N	16.18E	296	L.
51	74.58N	26.14E	210	C,L,N.
53	74.44N	26.19E	300	C,L.
1952(IV)				
27	72.33N	25.19E	210	B,L,N.
82	72.35N	23.29E	252	C.
1953(III)				
49	74.21N	24.44E	307	C.
50	74.22N	24.56E	311	C,N.
1953(IV)				
36	75.15N	25.37E	179	C.
37	75.10N	25.21E	165	C.
1953(VI)				
13	76.38N	33.23E	143	C.
28	76.45N	33.12E	140	C.
31	77.52N	30.00E	285	C.
42	77.21N	38.50E	212	C.
44	73.33N	41.48E	238	C.
47	76.55N	37.55E	182	C.
48	76.21N	37.55E	267	C,N.
51	75.30N	33.52E	234	N.
52	75.02N	32.23E	208	C,N.
53	74.55N	32.13E	210	N.
61	76.07N	21.05E	174	C.
1953(VII)				
13	77.52N	29.29E	249	C.
14	77.46N	29.08E	229	C.
16	77.15N	28.11E	182	C.
18	76.22N	29.08E	190	C.
19	76.15N	29.00E	165	C,N.
20	76.08N	28.48E	165	C.
21	76.10N	28.26E	143	C.
29	76.28N	33.15E	238	C.
30	76.36N	33.10E	165	C,N.

ERNEST HOLT. (Continued).

CRUISE & STATION.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
1953(VII) cont.				
31	76.53N	32.30E	210	C,H,M.
32	77.02N	32.15E	210	C.
33	77.02N	31.48E	227	C.
34	77.02N	31.14E	229	C,H.
35	76.44N	30.33E	278	C.
36	75.49N	27.12E	201	C.
37	75.49N	26.43E	165	N.
40	75.11N	26.51E	238	C.
41	75.11N	26.25E	225	C,N.
42	75.11N	26.00E	205	B,C,N.
48	75.59N	34.22E	229	C,N.
49	75.53N	34.22E	249	C,N.
50	75.46N	34.22E	205	C,N.
53	74.53N	32.38E	210	C,L,N.
54	74.47N	32.26E	216	C.
56	74.47N	25.00E	165	C,M.
59	74.17N	22.11E	219	C,L.
60	74.18N	22.43E	150	C.
61	74.18N	22.23E	165	C,L.
63	74.20N	22.34E	165	C,N.
1953(VIII)				
38	73.37N	49.54E	265	N.
39	73.32N	49.56E	274	C.
75	73.36N	37.58E	238	N.

CIROLANA (Dec,1972). (Unpublished).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
11	1.12.72	60.21N	47.10W	140	C,L,N.
12	1.12.72	60.21N	47.10W	140	C,N.
18	2.12.72	61.18N	49.59W	130	C.
19	3.12.72	61.37N	50.34W	130	N.
24	3.12.72	62.37N	51.34W	130	C,I,N.
25	3.12.72	62.26N	51.19W	140	C.
26	3.12.72	62.29N	51.17W	88	C.

CIROLANA (Aug, 1975). (Unpublished).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
34	27.8.75	74.31N	23.30E	160	C,M,N.
47	28.8.75	76.18N	24.53E	62	C,L,N.
86	3.9.75	77.23N	12.27E	180	C,L,M,N.

ICELAND (July,1978). (Palsson, personal communication).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
71	9.7.78	65.38N	13.22W	157	A,C,N.
76	11.7.78	65.07N	13.55W	183	C,N.
78	12.7.78	64.52N	13.11W	146	C,J,N.
79	12.7.78	64.46N	12.32W	174	C,N.
80	12.7.78	64.30N	12.59W	146	C,N.

ANTON DOHRN (1978).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
73	21.6.78	73.44N	20.27E	415	C,N.
74	21.6.78	73.52N	20.09E	306	C,N.
75	21.6.78	71.01N	19.15E	134	B,C,L,N.
76	21.6.78	74.07N	19.10E	80	C.
85	22.6.78	74.07N	16.18E	750	B,C,J,N.
87	23.6.78	74.21N	21.46E	200	B,C,M,N.
88	23.6.78	74.07N	22.03E	285	C,L,M,N.
89	23.6.78	74.03N	21.02E	300	C,N.
91	23.6.78	74.25N	21.08E	110	L,N.
98	24.6.78	76.31N	14.32E	230	C,L,N.
99	24.6.78	76.29N	14.18E	350	C,L,N.
100	24.6.78	76.45N	14.12E	125	N.
101	25.6.78	76.57N	13.55E	110	C,N.
102	25.6.78	76.56N	13.22E	215	B,C,L,N.
103	25.6.78	76.58N	12.15E	460	N.
105	26.6.78	77.28N	11.22E	285	B,C,N.
106	26.6.78	77.33N	11.58E	200	B,C,L,N.
107	26.6.78	77.26N	12.39E	210	C,L,M,N.
108	26.6.78	77.35N	13.05E	100	C,N.

ANTON DOHRN (Continued).

STATION.	DATE.	POSITION. LAT.	LONG.	DEPTH. (M)	SPECIES.
110	27.6.78	77.48N	10.33E	210	B,C,N.
111	27.6.78	77.52N	9.55E	300	N.
112	27.6.78	77.59N	9.30E	410	N.
113	27.6.78	78.06N	9.28E	510	J,N.
114	27.6.78	78.06N	9.55E	210	C,N,O.
115	3.7.78	73.53N	16.06E	415	B,J,N,O.
116	3.7.78	73.59N	16.35E	320	B,C,I,N.
117	3.7.78	74.21N	16.54E	206	B,J,N.
124	6.7.78	78.10N	10.00E.	260	N.
125	6.7.78	78.10N	9.26E	350	J,N.
126	6.7.78	78.15N	9.33E	450	C,I,J,N,O.
127	6.7.78	78.32N	9.20E	500	C,I,J,L,O.
128	6.7.78	78.36N	9.25E	400	B,C,J,N.
129	6.7.78	78.40N	9.28E	310	C,N.
134	7.7.78	79.10N	8.25E	510	C,N.
135	7.7.78	79.12N	8.21E	400	C,J,L,N,O.
136	7.7.78	79.17N	8.24E	255	N.
138	7.7.78	79.32N	8.53E	296	B,C,N.
141	9.7.78	76.37N	14.15E	245	B,C,N,O.
142	9.7.78	75.53N	14.38E	376	C,J,L,N.
143	9.7.78	75.46N	14.10E	460	B,C,L,N,O.
144	9.7.78	75.39N	14.04E	560	B,C,J,N,O.
147	10.7.78	74.34N	17.20E	152	B,C,L,N.
148	10.7.78	74.28N	16.43E	200	C,N.
149	10.7.78	74.30N	16.17E	300	B,C,N.
150	10.7.78	74.32N	16.11E	500	B,C,J,N.

WALTHER HERWIG (1979).

STATION.	DATE.	POSITION LAT.	LONG.	DEPTH (M)	SPECIES.
7	15.7.79	71.18N	22.19E	405	B.
9	15.7.79	71.32N	23.23E	373	O.
13	16.7.79	72.23N	22.19E	325	N,O.
14	16.7.79	72.25N	23.31E	277	C,N.
15	16.7.79	72.48N	23.31E	375	C,N.

WALTHER HERWIG (Continued).

STATION.	DATE.	POSITION. LAT.	POSITION. LONG.	DEPTH. (M)	SPECIES.
16	16.7.79	72.42N	21.52E	415	A,C.
19	17.7.79	73.00N	21.05E	455	A,C.
21	18.7.79	73.39N	18.49E	334	N,O.
23	18.7.79	73.17N	18.59E	465	A,C,N.
24	18.7.79	73.12N	17.23E	460	A,B,N,O.
25	18.7.79	73.36N	17.21E	407	A,B,N.
34	19.7.79	73.55N	16.21E	350	B,I,L,N.
35	19.7.79	74.05N	16.56E	258	A,B,C,L,M,N.
37	19.7.79	74.12N	16.44E	245	B,C,N.
38	19.7.79	74.25N	17.00E	190	C,N.
41	20.7.79	74.11N	20.48E	225	C,N.
42	20.7.79	74.03N	20.21E	137	B,L,N.
44	21.7.79	75.06N	17.08E	200	C,N.
45	21.7.79	75.12N	15.55E	240	C,N.
48	21.7.79	75.31N	14.48E	396	A,B,N.
49	21.7.79	75.36N	15.33E	380	C,N.
50	22.7.79	75.32N	16.18E	247	C,N.
51	22.7.79	75.36N	17.45E	150	C,N.
53	22.7.79	75.48N	16.33E	370	B,C,L,N.
54	22.7.79	75.57N	14.35E	326	B,C,L,N.
55	22.7.79	76.04N	15.26E	365	C,L,N.
57	23.7.79	76.17N	16.37E	130	N.
58	23.7.79	76.16N	17.00E	200	L,N.
59	23.7.79	76.11N	16.34E	260	C,N.
71	24.7.79	76.56N	12.37E	420	B,C,N,O.
72	25.7.79	77.05N	12.46E	475	A,N.
73	25.7.79	77.17N	12.44E	215	C,N.
74	25.7.79	77.08N	12.45E	190	B,C,L,N.
76	25.7.79	77.27N	13.10E	230	C,N.
78	26.7.79	78.13N	10.42E	280	C,L,N,O.
79	26.7.79	78.17N	10.12E	305	B,C,L,N.
80	26.7.79	78.13N	9.19E	500	C,N.
82	26.7.79	78.30N	9.30E	434	C,N.
86	27.7.79	80.07N	10.51E	370	C,L,N.
87	27.7.79	80.06N	11.06E	250	B,C,L,N.
111	29.7.79	79.21N	8.36E	167	C,L,N.

WALTHER HERWIG (Continued).

STATION.	DATE.	POSITION.		DEPTH.	SPECIES.
		LAT.	LONG.	(M)	
117	30.7.79	79.03N	9.39E	100	L.
121	31.7.79	78.34N	9.34E	199	C,N.
122	31.7.79	78.25N	10.56E	185	B,C,L,N.
130	3.8.79	77.39N	10.47E	353	C,N.
131	3.8.79	.44N	10.46E	247	C,N.
132	3.8.79	77.43N	11.40E	181	B,C,L,N.
133	3.8.79	77.42N	10.38E	350	C,N.
135	4.8.79	77.29N	11.09E	453	C,N.
137	4.8.79	77.16N	11.25E	452	A,B,O.
138	4.8.79	76.46N	13.16E	256	N.
139	4.8.79	76.34N	14.12E	175	A,B,C,L,N.
142	5.8.79	74.27N	16.17E	350	C,N.
143	5.8.79	74.22N	16.16E	460	B,L,N.
155	7.8.79	72.00N	26.39E	250	B.

APPENDIX III.

MEASUREMENT DATA.

The measurements made on eleven of the fifteen Eastern Arctic Nymphon species have been deposited in the following places.

a. With the Author.

b. Mrs P. Fry, Marine Benthos Laboratory, Putteridge Bury, Hitchin Road. Luton.

c. Crustacea Section, British Museum (Natural History), South Kensington, London.

The data consist of the following species and stations.

1. Nymphon tenellum, mixed stations from Eastern Arctic. (48 specimens).
2. Nymphon hirtipes, Sta 148, Anton Dohrn 1978 Cruise. (30 specimens).
3. Nymphon hirtipes, Sta 106, Anton Dohrn 1978 (30 specimens).
4. Nymphon hirtipes, Sta 107, Anton Dohrn 1978 (30 specimens).
5. Nymphon hirtipes, Sta 110, Anton Dohrn 1978 (30 specimens).
6. Nymphon hirtipes, Sta 110, Anton Dohrn 1978 (30 specimens).
7. Nymphon hirtipes, Sta 117, Anton Dohrn 1978 (30 specimens).
8. Nymphon hirtipes, Sta 127, Anton Dohrn 1978 (30 specimens).
9. Nymphon hirtipes, Sta 128, Anton Dohrn 1978 (30 specimens).
10. Nymphon hirtipes, Sta 129, Anton Dohrn 1978 (24 specimens).
11. Nymphon hirtipes, Stella Carina, Aug 1939 (30 specimens).
12. Nymphon hirtipes, Sta 86, Cirolana 1975 (30 specimens).
13. Nymphon hirtipes, Sta 11 & 12, Cirolana 1972 (26 specimens).
14. Nymphon hirtipes, Sta 80, Iceland 1978 (26 specimens).
15. Nymphon hirtipes, Sta 79, Iceland 1978 (13 specimens).
16. Nymphon hirtipes, Earnest Holt, Barents Sea (2 specimens).
17. Nymphon strömi, Sta 88 Anton Dohrn 1978 (30 specimens)

18. Nymphon strömi, Sta 98, Anton Dohrn 1978. (30 specimens).

19. Nymphon strömi, Sta 102, Anton Dohrn 1978 (30 specimens),

20. Nymphon strömi, Sta 106, Anton Dohrn 1978 (30 specimens).

21. Nymphon strömi, Sta 107, Anton Dohrn 1978 (30 specimens).

22. Nymphon strömi, Sta 116, Anton Dohrn 1978 (30 specimens).

23. Nymphon strömi, Sta 127, Anton Dohrn 1978 (30 specimens).

24. Nymphon strömi, Sta 128, Anton Dohrn 1978 (30 specimens).

25. Nymphon strömi, Sta 129, Anton Dohrn 1978 (30 specimens).

26. Nymphon strömi, Sta 141, Anton Dohrn 1978 (30 specimens).

27. Nymphon strömi, Sta 142, Anton Dohrn 1978 (30 specimens).

28. Nymphon stromi, Sta 86, Cirolana 1975 (29 specimens).

29. Nymphon strömi, Stas 79,37,52, 108, Cirlana 1978 (30 specimens).

30. Nymphon serratum, Various stations Anton Dohrn 1978 (26 specimens).

31. Nymphon megalops, Various stations Anton Dohrn 1978 (27 specimens).

32. Nymphon sluiteri, (Amsterdam collections)(30 specimens).

33. Nymphon grossipes, Various stations Anton Dohrn 1978 (60 specimens).

34. Nymphon elegans, White sea (Various) (30 specimens).

35. Nymphon longitarse, White sea (Various) (30 specimens).

36. Nymphon macronyx, White sea (Various) (30 specimens).

37. Nymphon longimanum White Sea (Various) (11 specimens).

The mensural variables for each specimens (18 primary and 23 in total) are given in full in table 2.1.

APPENDIX IV.

COMPUTER PROGRAMMES.

1. V.D.4 - Listing only.
2. CHECK 1. - Listing only.
3. FRYDA4 - Listing and example.
4. FRYDA6 - Listing and example.

VD4 LIST

```
1000 REM PROGRAM INPUTS DATA VIA VDU TO PYKNOS.DAT FILE.
1010 ! VERSION 29/6/79.
1020 ON ERROR GOTO 2620 \ Y$=SYS(CHR$(6%)+CHR$(-7%))
1030 DIM N$(5),C$(5),F$(5),S$(5,23)
1040 OPEN "DK0:PYKNOS.DAT" AS FILE 2%,MODE 1%
1050 FOR J=1 TO 5; FOR K=0 TO 23
1060    FIELD#2%,2 AS Q1$,2 AS Q2$,8 AS Q3$,100*(J-1) AS X1$,
      1 AS F$(J),2 AS N$(J),1 AS C$(J),4*K AS X2$,4 AS S$(J,K)
1070 NEXT K; NEXT J
1080 GET#2%,RECORD 1%
1090 B0%=CVT$%(Q1$) !B0% IS NO. BLOCKS IN USE IN FILE.
1100 A0%=CVT$%(Q2$) !A0% IS NO. OF ANIMALS STORED.
1110 PRINT CHR$(24%);"DATA INPUT PROGRAM."\PRINT"--------------------"
1120 PRINT\PRINT"CURRENT FILE DETAILS:-"\PRINT TAB(23);
1130 PRINT"NO. BLOCKS IN USE      ";B0% \PRINT TAB(23);
1140 PRINT"LARGEST ANIMAL NO. IS  ";A0% \PRINT
1150 PRINT"ANIMAL DATA CAN NOW BE ENTERED."\SLEEP 5
1160 DIM Y$(23),E$(6),L(23),X(23),E%(23)
1170 READ Y$(K) FOR K=0 TO 23  !VARIABLE NAMES.
1180 DATA "Y0 ","Y1 ","Y2 ","Y3 ","Y4 ","Y5 ","Y6 ","Y7 ","Y8 ","Y9 "
1190 DATA Y10,Y11,Y12,Y13,Y14,Y15,Y16,Y17,Y18,Y19,Y20,Y21,Y22,Y23
1200 MAT READ E$    !SEX CODES.
1210 DATA M,E,P,F,L,J
1220 READ L(K) FOR K=0 TO 23  !VARIABLE LIMITS.
1230 DATA 150,25,15,10,10,10,10,50,10,10,10,20,10,30,50,80,80,120
1240 DATA 20,20,10,60,10,10
1250 OPEN"KB:" AS FILE 1%,MODE 8%\Y$=SYS(CHR$(11%))
1260 DEF FNQ$(A$)  !OUTPUT STRING.
1270    PRINT #1%, RECORD 4096%, A$;
1280 FNEND
1290 DEF FNC%(X%,Y%)  !POSITION CURSOR.
1300    PRINT #1%, RECORD 4096%, CHR$(155%)+"Y"+CHR$(X%)+CHR$(Y%);
1310 FNEND  ! 0<=X%<=80  0<=Y%<=24
1320 X$=FNQ$(CHR$(24%))  !CLEAR SCREEN & CURSOR HOME.
1330 X$=FNQ$(CHR$(14%))  !SET HIGHLIGHT MODE.
1340 X$=FNQ$(CHR$(155%)+"L")  !SET INVERSE VIDEO.
1350 X$=FNQ$(" ") FOR K%=0% TO 80%  !LINE 0.
1360 P%=FNC%(0%,1%)  !MOVE TO LINE 1.
1370 X$=FNQ$(" ") FOR K%=0% TO 79%
1380 P%=FNC%(11%,1%)
1390 X$=FNQ$("SEA-SPIDER DATA INPUT PROGRAM.  VERSION 28/6/79.")
1400 X$=FNQ$(CHR$(6%))
1410 P%=FNC%(7%,3%)  !MOVE TO LINE 3.
1420 X$=FNQ$("ANIMAL NO.-----          SEX CODE -")
1430 FOR J%=0% TO 3% \ FOR K%=0% TO 5%  !LINES 5,7,9,11
1440    P%=FNC%(13%*K%+2%,2%*J%+5%)
1450    X$=FNQ$(Y$(6%*J%+K%))
1460    X$=FNQ$(" ------")  !PAINT 24 FIELDS
1470 NEXT K% \ NEXT J%
1480 FIELD #1%, 8 AS F$
1490 P%=FNC%(17%,3%)  !ANIMAL NO.
1500 PRINT #1%, RECORD 256%, CHR$(0%+5%)+"-";
1510 GET #1% \ L%=RECOUNT
1520 N1%=VAL(CVT$$(LEFT(F$,L%),-1%))
1530    IF N1%>A0% THEN 1600
1540    B1%=(N1%+4%)/5% \ P1%=N1%-5%*(B1%-1%)
1550    GET #2%, RECORD B1%
1560    N4%=CVT$%(N$(P1%)) \ IF N4%<>N1% THEN 1600
1570    P%=FNC%(6%,19%) \ X$=FNQ$(CHR$(14%))
1580    X$=FNQ$("CAUTION - DATA EXISTS FOR THIS ANIMAL NUMBER.")
1590    X$=FNQ$(CHR$(6%))
1600 P%=FNC%(40%,3%)  !SEX CODE.
1610 PRINT #1%, RECORD 256%, CHR$(0%+1%)+"-";
1620 GET #1%
1630 FOR J%=1% TO 6%
1640    IF LEFT(F$,1)=E$(J%) THEN 1680    !CHECK POSSIBLE SEX CODES.
1650 NEXT J%
1660 P%=FNC%(6%,22%) \ X$=FNQ$(CHR$(14%)) \ X$=FNQ$("SEX-CODE ERROR!")
1670 P%=FNC%(39%,3%) \ X$=FNQ$(" ") \ X$=FNQ$(CHR$(6%))
1680 S$=LEFT(F$,1%) \ MAT E%=ZER
1690 FOR J%=0% TO 3% \ FOR K%=0% TO 5%
1700    P%=FNC%(13%*K%+6%,2%*J%+5%)
1710    PRINT #1%, RECORD 256%, CHR$(0%+6%)+"-";
1720    GET #1% \ L%=RECOUNT
1730    N2=VAL(CVT$$(LEFT(F$,L%),-1%))
1740    I%=6%*J%+K%
1750    IF N2<L(I%) THEN 1790
1760    P%=FNC%(13%*K%+5%,2%*J%+5%)
1770    X$=FNQ$(CHR$(14%)) \ X$=FNQ$(" ") \ E%(I%)=1%
1780    P%=FNC%(6%,23%) \ X$=FNQ$("LIMIT ERROR!") \ X$=FNQ$(CHR$(6%))
1790    X(I%)=N2
```

```
1800 NEXT K% \ NEXT J%
1810 P%=FNC%(6%,13%)
1820 X$=FNQ$('TO ACCEPT TYPE 1 OR TO CORRECT TYPE 2 -')
1830 P%=FNC%(44%,13%)
1840 PRINT #1%, RECORD 256%, CHR$(0%+1%)+'-';
1850 GET #1% \ A$=LEFT(F$,1%)
1860 IF A$='1' THEN 2310 ELSE IF A$='2' THEN 1870 ELSE 1810
1870 P%=FNC%(6%,14%)
1880 X$=FNQ$('TO CORRECT ENTRIES TYPE 1 FOR ANIMAL NO., 2 FOR SEX CODE,')
1890 P%=FNC%(15%,15%)
1900 X$=FNQ$('OR 3 FOR A Y-VALUE  _')
1910 P%=FNC%(35%,15%)
1920 PRINT #1%, RECORD 256%, CHR$(0%+1%)+'_';
1930 GET #1% \ A$=LEFT(F$,1)
1940 IF A$='1'THEN1950 ELSEIF A$='2'THEN2000 ELSEIF A$='3'THEN2090 ELSE1870
1950 P%=FNC%(17%,3%) \ X$=FNQ$('_____') \ P%=FNC%(17%,3%)
1960 PRINT #1%, RECORD 256%, CHR$(0%+5%)+'_';
1970 GET #1% \ L%=RECOUNT
1980 N1%=VAL(CVT$$(LEFT(F$,L%),-1%))
1990 GOTO 2270
2000 P%=FNC%(39%,3%) \ X$=FNQ$(' _') \ P%=FNC%(40%,3%)
2010 PRINT #1%, RECORD 256%, CHR$(0%+1%)+'_';
2020 GET #1% \ S$=LEFT(F$,1)
2030 FOR J%=1% TO 6%
2040    IF S$=E$(J%) THEN 2070
2050 NEXT J% \ P%=FNC%(39%,3%) \ X$=FNQ$(CHR$(14%))
2060 X$=FNQ$(' ') \ X$=FNQ$(CHR$(6%)) \ GOTO 2270
2070 P%=FNC%(6%,22%) \ X$=FNQ$('                    ')
2080 GOTO 2270
2090 P%=FNC%(6%,16%) \ X$=FNQ$('WHICH Y-VALUE  __') \ P%=FNC%(21%,16%)
2100 PRINT #1%, RECORD 256%, CHR$(0%+2%)+'_';

2110 GET #1%
2120 K=VAL(CVT$$(LEFT(F$,2%),-1%))
2130 J%=INT(K/6+0.1) \ K%=K-6%*J%
2140 P1%=13%*K%+5% \ P2%=2%*J%+5%
2150 E%(K)=0% \ T%=0%
2160 T%=T%+E%(J%) FOR J%=0% TO 23%
2170 IF T%<>0% THEN 2190
2180 P%=FNC%(6%,23%) \ X$=FNQ$('            ')
2190 P%=FNC%(P1%,P2%) \ X$=FNQ$(' ______') \ P%=FNC%(P1%+1%,P2%)
2200 PRINT #1%, RECORD 256%, CHR$(0%+6%)+'_';
2210 GET #1% \ L%=RECOUNT \ N2=VAL(CVT$$(LEFT(F$,L%),-1%))
2220 IF N2<L(K) THEN 2260
2230 E%(K)=1% \ P%=FNC%(P1%,P2%) \ X$=FNQ$(CHR$(14%))
2240 X$=FNQ$(' ') \ P%=FNC%(6%,23%)
2250 X$=FNQ$('CHECK LIMIT!') \ X$=FNQ$(CHR$(6%))
2260 X(K)=N2                        !Y-VALUE IN TEMP STORE.
2270 P%=FNC%(6%,18%) \ X$=FNQ$('ANY OTHER CORRECTIONS?  Y OR N  _')
2280 P%=FNC%(38%,18%) \ PRINT #1%, RECORD 256%, CHR$(0%+1%)+'_';
2290 GET #1% \ A$=LEFT(F$,1%)
2300 IF A$='Y'THEN 1890 ELSE IF A$='N' THEN 2310 ELSE 2270
2310 P%=FNC%(6%,20%) \ X$=FNQ$(CHR$(14%)) \ X$=FNQ$('DATA COMPLETE.')
2320 X$=FNQ$(CHR$(6%)) \ SLEEP 5
2330 B1%=(N1%+4%)/5% \ P1%=N1%-5%*(B1%-1%)
2350 GET #2%, RECORD B1%
2360 LSET F$(P1%)='A'               !FLAG AS ACTIVE.
2370 LSET N$(P1%)=CVT%$(N1%)        !ANIMAL NO.
2380 LSET C$(P1%)=S$                !SEX-CODE.
2390 FOR I%=0% TO 23%
2400    LSET S$(P1%,I%)=CVTF$(X(I%))    !Y-VALUES AS CHARS.
2410 NEXT I%
2420 PUT #2%, RECORD B1%            !STORE DATA FOR ANIMAL.
2430 IF N1%<=A0% THEN 2500
2440 GET #2%, RECORD 1%             !STORE FILE DATA.
2470 LSET Q1$=CVT%$(B1%)            !STORE NO. BLOCKS.
2480 LSET Q2$=CVT%$(N1%)            !STORE NO. ANIMALS.
2490 PUT #2%, RECORD 1%
2500 X$=FNQ$(CHR$(24%)) \ P%=FNC%(6%,3%)
2510 X$=FNQ$('IS ANOTHER ANIMAL TO BE ADDED?  Y OR N  _')
2520 UNLOCK #2%
2530 P%=FNC%(46%,3%) \ PRINT #1%, RECORD 256%, CHR$(0%+1%)+'_';
2540 GET #1% \ SLEEP 3 \ A$=LEFT(F$,1%)
2550 IF A$='Y'THEN 1320 ELSE IF A$='N'THEN 2560 ELSE 2500
2560 P%=FNC%(6%,10%) \ X$=FNQ$('END OF ALL DATA INPUT.')
2570 GET #2%, RECORD 1%
2580 C$=LEFT(Q3$,1)
2590 IF C$='A' THEN LSET Q3$='B' ELSE LSET Q3$='A'
```

```
2600 PUT #2%, RECORD 1%
2610 GOTO 2700
2620 IF ERR<>52 THEN 2650
2630 X$=FNQ$(CHR$(7%)) FOR D=1 TO 100
2640 RESUME 1700
2650 IF ERR<>19 THEN 2670
2660 SLEEP 5 \ RESUME
2670 X$=FNQ$(CHR$(24%))
2680 X$=FNQ$("ERROR HAS OCCURRED! THIS ANIMAL DATA IS LOST!")
2690 SLEEP 4 \ RESUME 1320

2700 CLOSE 1%,2% \SLEEP 4
2710 PRINT CHR$(12);"FILE MUST NOW BE COPIED"
2720 PRINT\PRINT"LOAD TAPE ";C$
2730 PRINT\PRINT"PRESS RETURN TO COPY TAPE."
2740 PRINT\INPUT Z9$
2750 Y$=SYS(CHR$(8%)+"PIP MT0:PYKNOS.DAT/MO:16=PYKNOS.DAT")
2760 CHAIN "$PIPEXT" 30000
2770 END
```

CHECK 1 LIST

```
CHECK1.BAS

1000 REM CHECK PROGRAM TO LIST ENTRIES IN SPIDER.DAT
1010 ON ERROR GOTO 2360 \ Y$=SYS(CHR$(6%)+CHR$(-7%))
1020 DIM N$(5),C$(5),F$(5),S$(5,23)
1030 OPEN "DK0:SPIDER.DAT" AS FILE 2%,MODE 1%
1040 FOR J=1 TO 5: FOR K=0 TO 23
1050     FIELD#2%,2 AS G1$,2 AS G2$,8 AS G3$,100*(J-1) AS X1$,
       1 AS F$(J),2 AS N$(J),1 AS C$(J),4*K AS X2$,4 AS S$(J,K)
1060 NEXT K: NEXT J
1100 PRINT CHR$(24%);"PROGRAM CHECKS ENTRIES IN SPIDER.DAT"
1110 PRINT "-"; FOR N=1 TO 36 \ PRINT
1120 PRINT "WHICH ANIMAL";
1130 INPUT N1%
1140 B1%=(N1%+4%)/5% \ P1%=N1%-5%*(B1%-1%)
1150 GET#2%,RECORD B1%
1160 PRINT\PRINT"ANIMAL NO. IS ";CVT$%(N$(P1%))
1170 PRINT"SEX-CODE IS ";C$(P1%)
1180 PRINT"Y-VALUES ARE:-"
1190 FOR R%=0% TO 3%
1200     FOR C%=0% TO 5%
1210         M%=C%+6%*R% \ V=CVT$F(S$(P1%,M%))
1220         PRINT USING"  Y##=###.###";M%,V;
1230     NEXT C% \ PRINT
1240 NEXT R%
1250 PRINT\PRINT"IS ANOTHER ANIMAL TO BE CHECKED?  Y OR N";
1255 UNLOCK #2%
1260 INPUT A$
1270 IF A$="Y" THEN 1100
2350 GOTO 2370
2360 PRINT"ERROR!"
2370 CLOSE 2%
2390 END
```

DA4 LIST

```
100 REM A STATISTICAL PROGRAM PROCESSING SPIDER.DAT
101 ! VERSION 12-JUL-79.
105 PRINT CHR$(12);"PROGRAM - FR(DA4."
110 PRINT"-";FOR X=1 TO 17:PRINT:PRINT
115 PRINT"STATISTICAL PROGRAM TO PROCESS SPIDER.DAT FILE."
120 ON ERROR GOTO 570: Y$=SYS(CHR$(6%)+CHR$(-7%))
125 DIM N$(5),S$(5,23),C$(5),F$(5),V(100)
130 OPEN "DK0:SPIDER.DAT" AS FILE 1%, MODE 1%
135 FOR J=1 TO 5   FOR K=0 TO 23
140     FIELD#1%,2 AS G1$,2 AS G2$,8 AS G3$,100*(J-1) AS X1$,
        1 AS F$(J),2 AS N$(J),1 AS C$(J),4*K AS X2$,4 AS S$(J,K)
145 NEXT K: NEXT J
150 PRINT:PRINT"SECTION 1.":PRINT"----------"
155 PRINT:PRINT"CORRELATION & CURVE FITTING."
160 PRINT:PRINT"WHICH 2 Y'S ARE TO BE COMPARED?"
165 PRINT"   N.B. FIRST Y IS Y(0)."
170 INPUT "Y NUMBERS"; Y1%,Y2%
175 PRINT"HOW MANY PAIRS OF VALUES ARE TO BE USED";
180 INPUT N%
185 DIM L%(400): MAT L%=ZER(N%)
190 DIM X(400),Y(400)
192 MAT X=ZER(N%): MAT Y=ZER(N%)
195 PRINT"TYPE IN THE"N%"ANIMAL NUMBERS."
200 MAT INPUT L%(N%)
205 PRINT"CHECK!  THE"N%"ANIMALS ARE:-"
210 PRINT USING "####" L%(0%); FOR 0%=1% TO N%
215 PRINT:PRINT"IS THAT CORRECT?  TYPE (ES OR NO"
220 INPUT A$: IF A$="YES"THEN 225 ELSE IF A$="NO" THEN 175 ELSE 215
225 DIM S(11),W%(5,5)\ PRINT
230 MAT S=ZER: B9%=0%
235 PRINT USING"   COUNT  ANIMAL  VAR##     VAR##" Y1%,Y2%
240 PRINT"  ---------------------------------"
242 N9%=N%\ M=0
245 FOR K%=1% TO N%
250     B%=(L%(K%)+4%)/5% \ S%=L%(K%)-5%*(B%-1%)
255     REM B% IS BLOCK & S% THE SUB-RECORD.
260     IF B%=B9% THEN 270
265     GET#1%,RECORD B%
270     B9%=B%
275     X=CVT$F(S$(S%,Y1%)):  Y=CVT$F(S$(S%,Y2%))
276     IF X =0 AND Y =0 THEN 280
277     PRINT"VALUE(S) MISSING - ANIMAL"L%(K%)" - ANIMAL DELETED."
278     N9%=N9%-1%:X(K%)=-1:GOTO 305
280     X(K%)=X\ Y(K%)=Y\ M=M+X
295     S(11%)=S(11%)+Y*Y
300     PRINT USING"    ###    ###    ####.##    ####.##" K%,L%(K%),X,Y
305 NEXT K%:Q1=0:CLOSE 1%:F9=1
306 M=M/N9%\ PRINT\ PRINT"MEAN IS ";M
307 FOR K%=1% TO N%
308     IF X(K%)=-1 THEN 311 ELSE X(K%)=X(K%)-M
309     S(P%)=S(P%)+X(K%)^P% FOR P%=0% TO 6%
310     S(P%+7%)=S(P%+7%)+Y(K%)*X(K%)^P% FOR P%=0% TO 3%
311 NEXT K%
315 PRINT:PRINT"GENERAL REGRESSION ANALYSIS."
320 PRINT"-"; FOR Q=1 TO 22:PRINT: W=S(11)-S(7)*S(7)/N9%
325 PRINT: DIM A(4,4),I(4,4),B(4),Z(4)
330 M1$="NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL."
335 M2$="NEW TERM IS SIGNIFICANT AT 1% LEVEL."
340 FOR Q=2 TO 4
345     MAT A=ZER(Q,Q)\MAT B=ZER(Q)\MAT Z=ZER(Q)
350     A(J,K)=S(J+K-2) FOR J=1 TO Q FOR K=1 TO Q.
355     B(J)=S(J+6) FOR J=1 TO Q
360     GOSUB 600
365     PRINT"TO FIT"Q"COEFFICIENTS."
370     PRINT"-"; FOR H=1 TO 22:PRINT:PRINT"FORM IS - ";:T=0
371     ON Q-1 GOTO 372,373,374
372     PRINT"Y=A+B.(X-M)  WHERE"\ GOTO 375
373     PRINT"Y=A+B.(X-M)+C.(X-M)^2  WHERE"\ GOTO 375
374     PRINT"Y=A+B.(X-M)+C.(X-M)^2+D.(X-M)^3  WHERE"\ GOTO 375
375     PRINT CHR$(64+H);" = ";Z(H) FOR H=1 TO Q
377     PRINT"   AND WHERE M IS ";M
380     FOR J%=1% TO N%
382         IF X(J%)=-1 THEN 400
385         V(J%)=Z(1%)
390         V(J%)=V(J%)+Z(K%+1%)*X(J%)^K% FOR K%=1% TO Q-1
395         T=T+(V(J%)-Y(J%))^2
```

```
400     NEXT J%:PRINT:N%=N9%
405     L=W-T: L1=0-1: L2=L/L1
410     T1=N%-0: T2=T/T1: F=L2/T2
415     U$="-": U$=U$+"-" FOR H=1 TO 36
420     PRINT"SOURCE       SOS      N     VAR      F": PRINT U$
425     PRINT USING"LINE      ####.##  ### ###.## ###.##";L,L1,L2,F
430     R3=L-Q3\ IF 0=2 THEN 445
435     PRINT USING" [ PREV. ####.##  ### ###.## ###.## ]";Q3,Q1,Q2,Q2/T2
440     PRINT USING" [ NEW   ####.##  ### ###.## ###.## ]";R3,1,R3,R3/T2
445     PRINT USING"RESIDUAL ####.##  ### ###.##";T,T1,T2
450     PRINT U$:PRINT USING"TOTAL     ####.## ####";W,N%-1%
455     PRINT: ON 0 GOTO 570,460,485,510
460     F1=6.63+24.767/T1+93.333/T1^2: IF F<F1 THEN 480
465     PRINT"LINEAR FIT IS SATISFACTORY AT 1% LEVEL.": 01=1
470     Z=(S(8)*N%-S(1)*S(7))/SQR((S(2)*N%-S(1)^2)*(S(11)*N%-S(7)^2))
475     PRINT"CORRELATION COEFFICIENT IS";:PRINT USING" #.##";Z: GOTO 535
480     PRINT"LINEAR FIT NOT SATISFACTORY AT 1% LEVEL.":GOTO 535
485     F1=4.61+20.333/T1+91.667/T1^2: IF F<F1 THEN 505
490     PRINT"QUADRATIC FIT IS SATISFACTORY AT 1% LEVEL."
495     IF(6.63+24.767/T1+93.333/T1^2)<R3/T2 THEN PRINT M1$
         ELSE PRINT M2$\01=2
500     GOTO 535
505     PRINT"QUADRATIC FIT NOT SATISFACTORY AT 1% LEVEL.":GOTO 535
510     IF(3.78+19.033/T1+86.667/T1^2)<F THEN 530
515     PRINT"CUBIC FIT IS SATISFACTORY AT 1% LEVEL."
520     IF(6.63+24.767/T1+93.333/T1^2)<R3/T2 THEN PRINT M1$
         ELSE PRINT M2$\01=3
525     GOTO 535
530     PRINT"CUBIC FIT IS NOT SATISFACTORY AT 1% LEVEL."
535     PRINT\PRINT\ Q3=L\Q1=L1\Q2=L2
540 NEXT 0
545 PRINT"   CONCLUSION. ";: ON 01+1 GOTO 550,555,560,565
550 PRINT"NO SIGNIFICANT PATTERN HAS BEEN FOUND.": GOTO 585
555 PRINT"BEST FIT IS LINEAR.": GOTO 585
560 PRINT"BEST FIT IS QUADRATIC.": GOTO 585
565 PRINT"BEST FIT IS CUBIC.": GOTO 585
570 PRINT "ERROR HAS OCCURED. LINE NO."ERL" & ERROR NO."ERR
575 PRINT"CURRENT DATA-BLOCK MAY HAVE BEEN CORRUPTED."
580 Y$=SYS(CHR$(6%)+CHR$(-7%))
585 IF F9=1 THEN 595
590 CLOSE 1%
595 PRINT\ PRINT"END OF RUN.": GOTO 900
600 MAT I=IDN(0,0)\MAT W%=ZER(0,0)
610 FOR I1=1 TO 0
620   X,P,Q=0
630   FOR J1=1 TO 0\ FOR K1=1 TO 0
640     IF ABS(A(J1,K1))<=X OR W%(J1,K1)<>0% THEN 660
650     X=ABS(A(J1,K1))\ P=J1\ Q=K1
660   NEXT K1\ NEXT J1     ! (P,Q) IS THE PIVOT.
670   FOR K1=1 TO 0
680     W%(P,K1),W%(K1,Q)=1%
690   NEXT K1\ W%(P,Q)=2%
700   FOR J1=1 TO 0
710     IF J1=P THEN 770
720     R=A(J1,Q)/A(P,Q)
730     FOR K1=1 TO 0
740       A(J1,K1)=A(J1,K1)-R*A(P,K1)
750       I(J1,K1)=I(J1,K1)-R*I(P,K1)
760     NEXT K1
770   NEXT J1\ R=A(P,Q)
780   FOR K1=1 TO 0
790     A(P,K1)=A(P,K1)/R \ I(P,K1)=I(P,K1)/R
800   NEXT K1
810 NEXT I1
820 MAT Z=I*B\ RETURN
900 END
```

DA4 EXAMPLE

```
STATISTICAL PROGRAM TO PROCESS SPIDER.DAT FILE.

SECTION 1.
----------

CORRELATION & CURVE FITTING.

WHICH 2 Y'S ARE TO BE COMPARED?
   N.B.  FIRST Y IS Y(0).
Y NUMBERS? 0,1
HOW MANY PAIRS OF VALUES ARE TO BE USED? 30
TYPE IN THE 30 ANIMAL NUMBERS.
? 670,671,672,673,674,674\4\5,676,677,6789\9\,679,680,681,682,683,684,68
5,686,687,688,689,690,691,692,693,694,695,696,697,698,699
? CHECK!  THE 30 ANIMALS ARE:-
 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687
 688 689 690 691 692 693 694 695 696 697 698 699
IS THAT CORRECT?  TYPE YES OR NO
?

IS THAT CORRECT?  TYPE YES OR NO
? YES

   COUNT  ANIMAL  VAR 0      VAR 1
  ------------------------------
      1    670      82.42       9.28
      2    671      56.74       8.00
      3    672      70.30       7.68
      4    673      73.48       8.80
      5    674      61.20       9.12
      6    675      59.22       8.00
      7    676      63.76       9.28
      8    677      52.64       7.52
      9    678      56.32       7.36
     10    679      72.36       8.64
     11    680      63.34       9.12
     12    681      55.28       6.56
     13    682      65.72       8.80
     14    683      57.48       7.36
     15    684      73.24       8.96
     16    685      71.20       8.80
     17    686      71.28       8.32
     18    687      53.12       7.52
     19    688      54.08       6.72
     20    689      52.16       6.88
     21    690      63.68       8.48
     22    691      60.96       8.00
     23    692      64.08       7.84
     24    693      59.22       8.00
     25    694      51.36       6.04
     26    695      76.74       8.80
     27    696      66.24       9.12
     28    697      71.96       8.64
     29    698      55.68       8.00
     30    699      55.60       6.56

MEAN IS  63.026
```

```
REM A STATISTICAL PROGRAM PROCESSING SPIDER.DAT
 ! VERSION 7-NOV-1979.
 PRINT CHR$(12);"PROGRAM - FRIDAY.  VERSION 7-NOV-79."
 PRINT"-"; FOR K=1 TO 37\ PRINT\ PRINT
PRINT"STATISTICAL PROGRAM TO PROCESS SPIDER.DAT FILE."
ON ERROR GOTO 604: Y$=SYS(CHR$(6%)+CHR$(-7%))
DIM N$(5),S$(5,23),C$(5),F$(5),V(500)
OPEN "DK0:SPIDER.DAT" AS FILE 1%, MODE 1%
FOR J=1 TO 5 \ FOR K=0 TO 23
    FIELD#1%,2 AS Q1$,2 AS Q2$,8 AS Q3$,100*(J-1) AS X1$,
    1 AS F$(J),2 AS N$(J),1 AS C$(J),4*K AS X2$,4 AS S$(J,K)
NEXT K: NEXT J
PRINT:PRINT"SECTION 1.":PRINT"----------"
PRINT:PRINT"CORRELATION & CURVE FITTING."
PRINT:PRINT"WHICH 2 Y'S ARE TO BE COMPARED?"
PRINT"   N.B. FIRST Y IS Y(0)."
INPUT "Y NUMBERS"; Y1%,Y2%
DIM N%(3),L2%(1000),T(9,4),L$(500)
 FOR G%=1% TO 3%
 ON G% GOTO 176,180,288
 PRINT\PRINT"SAMPLE ONE."\GOTO 184
 PRINT CHR$(12)\ PRINT "SAMPLE TWO."
 PRINT"-----------"\PRINT
 INPUT "HOW MANY PAIRS OF VALUES IN THIS SAMPLE";N%(G%)
 N%=N%(G%)
DIM L%(500),X(500),Y(500)\ MAT L%=ZER(N%)
PRINT"TYPE IN THE"N%"ANIMAL NUMBERS."
MAT INPUT L$\ P=1
FOR F%=1% TO 500%
  L$=L$(F%)\ H%=LEN(L$(F%))
  FOR K%=1% TO H%
     IF MID(L$,K%,1)="-" THEN 232
  NEXT K%
  L%(P)=VAL(L$)\ P=P+1\ IF P>N% THEN 252 ELSE 248
  N1=VAL(LEFT(L$,K%-1%))\ N2=VAL(RIGHT(L$,K%+1%))
  FOR H=N1 TO N2+0.1
     L%(P)=H\ P=P+1\ IF P>N% THEN 252
  NEXT H
NEXT F%
PRINT"CHECK! ";(P-1);"ANIMALS ENTERED.  THEIR NUMBERS WERE:-"
PRINT USING"######" L%(Q%); FOR Q%=1% TO N%
PRINT:PRINT"IS THAT CORRECT?  TYPE YES OR NO"
INPUT A$\IF A$="YES"THEN 268 ELSE IF A$="NO"THEN 776 ELSE 260
 ON G% GOTO 272,280
 L2%(K%)=L%(K%) FOR K%=1% TO N%
 GOTO 304
 L2%(K%+N%(1%))=L%(K%) FOR K%=1% TO N%
 N%(3%)=N%(1%)+N%(2%): GOTO 304
 PRINT CHR$(12)\PRINT"POOLED SAMPLES."
 PRINT "---------------"\ PRINT
 N%=N%(3%): MAT L%=ZER(N%)
 L%(L9%)=L2%(L9%) FOR L9%=1% TO N%
 DIM S(11),W%(5,5)\PRINT
 MAT S=ZER\ S(0)=0\ B9%=0%
N9%=N%\ M=0
FOR K%=1% TO N%

    B%=(L%(K%)+4%)/5% \ S%=L%(K%)-5%*(B%-1%)
    REM B% IS BLOCK & S% THE SUB-RECORD.
    IF B%=B9% THEN 336
    GET#1%,RECORD B%
    B9%=B%
    X=CVT$F(S$(S%,Y1%)):  Y=CVT$F(S$(S%,Y2%))
    IF X=0 AND Y=0 THEN 356
    PRINT"VALUE(S) MISSING - ANIMAL"L%(K%)" - ANIMAL DELETED."
    N9%=N9-1%\X(K%)=-1\GOTO 364
    X(K%)=X\ Y(K%)=Y\ M=M+X
    S(11%)=S(11%)+Y*Y
NEXT K%\01=0\ IF G%<3% THEN 372
CLOSE 1%\F9=1
M=M/N9%\PRINT
FOR K%=1% TO N%
    IF X(K%)=-1 THEN 392 ELSE X(K%)=X(K%)-M
    S(P%)=S(P%)+X(K%)^P% FOR P%=0% TO 6%
    S(P%+7%)=S(P%+7%)+Y(K%)*X(K%)^P% FOR P%=0% TO 3%
NEXT K%
W=S(11)-S(7)*S(7)/N9%
PRINT: DIM A(4,4),I(4,4),B(4),Z(4)
M1$="NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL."
M2$="NEW TERM IS SIGNIFICANT AT 1% LEVEL."
FOR O=2 TO 4
    MAT A=ZER(O,O)\MAT B=ZER(O)\MAT Z=ZER(O)
    A(J,K)=S(J+K-2) FOR J=1 TO O FOR K=1 TO O
    B(J)=S(J+6) FOR J=1 TO O
    GOSUB 628
```

```
432     PRINT'TO FIT'O'COEFFICIENTS.'
436     PRINT'-'; FOR H=1 TO 22:PRINT:PRINT'FORM IS - ';:T=0
440     ON O-1 GOTO 444,448,452
444     PRINT'Y=A+B.(X-M)  WHERE'\ GOTO 456
448     PRINT'Y=A+B.(X-M)+C.(X-M)^2  WHERE'\ GOTO 456
452     PRINT'Y=A+B.(X-M)+C.(X-M)^2+D.(X-M)^3  WHERE'\ GOTO 456
456     PRINT CHR$(64+H);' = ';Z(H) FOR H=1 TO O
460     PRINT'   AND WHERE M IS ';M
464     FOR J%=1% TO N%
468        IF X(J%)=-1 THEN 484
472        V(J%)=Z(1%)
476        V(J%)=V(J%)+Z(K%+1%)*X(J%)^K% FOR K%=1% TO O-1
480        T=T+(V(J%)-Y(J%))^2
484     NEXT J%:PRINT:N%=N9%
488     L=W-T: L1=O-1: L2=L/L1
492     T1=N%-O: T2=T/T1: F=L2/T2
496 R=3%*G%+O-4
500 T(R,1)=T\T(R,2)=T1\T(R,3)=T2
504     PRINT: ON O GOTO 604,508,528,548
508     F1=6.63+24.767/T1+93.333/T1^2: IF F<F1 THEN 524
512     PRINT'LINEAR FIT IS SATISFACTORY AT 1% LEVEL.': O1=1
516     Z=(S(8)*N%-S(1)*S(7))/SQR((S(2)*N%-S(1)^2)*(S(11)*N%-S(7)^2))
520     PRINT'CORRELATION COEFFICIENT IS';:PRINT USING' #.##'Z: GOTO 568
524     PRINT'LINEAR FIT NOT SATISFACTORY AT 1% LEVEL.':GOTO 568
528     F1=4.61+20.333/T1+91.667/T1^2: IF F<F1 THEN 544
532     PRINT'QUADRATIC FIT IS SATISFACTORY AT 1% LEVEL.'
536     IF(6.63+24.767/T1+93.333/T1^2)>R3/T2 THEN PRINT M1$
         ELSE PRINT M2$\O1=2
540     GOTO 568
544     PRINT'QUADRATIC FIT NOT SATISFACTORY AT 1% LEVEL.':GOTO 568
548     IF(3.78+19.033/T1+86.667/T1^2)>F THEN 564
552     PRINT'CUBIC FIT IS SATISFACTORY AT 1% LEVEL.'
556     IF(6.63+24.767/T1+93.333/T1^2)>R3/T2 THEN PRINT M1$
         ELSE PRINT M2$\O1=3
560     GOTO 568
564     PRINT'CUBIC FIT IS NOT SATISFACTORY AT 1% LEVEL.'
568     PRINT\PRINT\ Q3=L\Q1=L1\Q2=L2
572 NEXT O
576 PRINT'   CONCLUSION. ';: ON O1+1 GOTO 580,584,588,592
580 PRINT 'NO SIGNIFICANT PATTERN HAS BEEN FOUND.'\GOTO 596
584 PRINT'BEST FIT IS LINEAR.'\GOTO 596
588 PRINT'BEST FIT IS QUADRATIC.'\GOTO 596
592 PRINT'BEST FIT IS CUBIC.'
596 T(R,4)=O1\NEXT G%
600 GOTO 616
604 PRINT 'ERROR HAS OCCURED, LINE NO.'ERL' & ERROR NO.'ERR
608 PRINT'CURRENT DATA-BLOCK MAY HAVE BEEN CORRUPTED.'
612 Y$=SYS(CHR$(6%)+CHR$(-7%))
616 IF F9=1 THEN 624
620 CLOSE 1%
624 IF O1=0 THEN 772 ELSE 720
628 MAT I=IDN(O,O)\MAT W%=ZER(O,O)
632 FOR I1=1 TO O
636   X,P,Q=0
640   FOR J1=1 TO O\ FOR K1=1 TO O
644     IF ABS(A(J1,K1))<=X OR W%(J1,K1)<>0% THEN 652
648     X=ABS(A(J1,K1))\ P=J1\ Q=K1
652   NEXT K1\ NEXT J1     ! (P,Q) IS THE PIVOT.
656   FOR K1=1 TO O
660     W%(P,K1),W%(K1,Q)=1%
664   NEXT K1\ W%(P,Q)=2%
668   FOR J1=1 TO O
672     IF J1=P THEN 696
676     R=A(J1,Q)/A(P,Q)
680     FOR K1=1 TO O
684       A(J1,K1)=A(J1,K1)-R*A(P,K1)
688       I(J1,K1)=I(J1,K1)-R*I(P,K1)
692     NEXT K1
696   NEXT J1\ R=A(P,Q)
700   FOR K1=1 TO O
704     A(P,K1)=A(P,K1)/R \ I(P,K1)=I(P,K1)/R
708   NEXT K1
712 NEXT I1
716 MAT Z=I*B\ RETURN
720 PRINT CHR$(12)
724 PRINT'   SOURCE        SOS      DF      VAR      F'
728 PRINT'-'; FOR K%=1% TO 39% \PRINT
732 PRINT USING'    REG.1     ###.##  ###   ###.##'T(O1,1),T(O1,2),T(O1,3)
736 K=O1+3\L=O1+6
740 PRINT USING'    RES.2     ###.##  ###   ###.##'T(K,1),T(K,2),T(K,3)
744 PRINT '-'; FOR K%=1% TO 39%\ PRINT
748 PRINT USING'RES. POOLED ###.##  ###   ###.##'T(L,1),T(L,2),T(L,3)
752 PRINT '-'; FOR K%=1% TO 39%\ PRINT
756 T1=T(O1,1)+T(K,1)\T2=T(O1,2)+T(K,2)\T3=T1/T2
760 R=T(L,3)/T3
764 PRINT USING'SUM RES.1&2 ###.##  ###   ###.##  ###.##'T1,T2,T3,R
768 PRINT FOR K=1 TO 3
772 PRINT'END OF ANALYSIS.'\ GOTO 800
776 INPUT'WHICH ARE TO BE RE-ENTERED?  TYPE ALL OR SOME.' A$
780 IF A$='ALL' THEN 188 ELSE IF A$='SOME' THEN 784 ELSE 776
784 PRINT'TYPE POSITION OF INCORRECT ITEM IN LIST & CORRECT VALUE.'
788 INPUT M1%,M2%\ L%(M1%)=M2%
792 PRINT'ANY OTHER CORRECTIONS?  YES OR NO';\ INPUT A$
796 IF A$='YES'THEN 784 ELSE IF A$='NO' THEN 252 ELSE 792
```

DA6 EXAMPLE

```
STATISTICAL PROGRAM TO PROCESS PYKNOS.DAT FILE.

SECTION 1.
----------

CORRELATION & CURVE FITTING.

WHICH 2 Y'S ARE TO BE COMPARED?
   N.B.  FIRST Y IS Y(0).
Y NUMBERS? 0,17

SAMPLE ONE.
-----------

HOW MANY PAIRS OF VALUES IN THIS SAMPLE? 30
TYPE IN THE 30 ANIMAL NUMBERS.
? 283-312
CHECK!  30 ANIMALS ENTERED.  THEIR NUMBERS WERE:-
   283   284   285   286   287   288   289   290   291   292   293   294
   295   296   297   298   299   300   301   302   303   304   305   306
   307   308   309   310   311   312
IS THAT CORRECT?  TYPE YES OR NO
? YES


TO FIT 2 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)  WHERE
A =  23.308
B =  .738224
   AND WHERE M IS  32.9507

LINEAR FIT IS SATISFACTORY AT 1% LEVEL.
CORRELATION COEFFICIENT IS 0.99


TO FIT 3 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)+C.(X-M)^2  WHERE
A =  23.1973
B =  .746262
C =  .447178E-2
   AND WHERE M IS  32.9507

QUADRATIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.


TO FIT 4 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)+C.(X-M)^2+D.(X-M)^3  WHERE
A =  23.1968
B =  .734486
C =  .482596E-2
D =  .184241E-3
   AND WHERE M IS  32.9507

CUBIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.

   CONCLUSION.  BEST FIT IS LINEAR.
```

```
SAMPLE TWO.
-----------

HOW MANY PAIRS OF VALUES IN THIS SAMPLE? 30
TYPE IN THE 30 ANIMAL NUMBERS.
? 229-258
CHECK!  30 ANIMALS ENTERED.  THEIR NUMBERS WERE:-
   229   230   231   232   233   234   235   236   237   238   239   240
   241   242   243   244   245   246   247   248   249   250   251   252
   253   254   255   256   257   258
IS THAT CORRECT?  TYPE YES OR NO
? YES


TO FIT 2 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)  WHERE
A =  18.4797
B =  .730717
   AND WHERE M IS  26.2757


LINEAR FIT IS SATISFACTORY AT 1% LEVEL.
CORRELATION COEFFICIENT IS 0.98


TO FIT 3 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)+C.(X-M)^2  WHERE
A =  18.4845
B =  .772416
C =  .622076E-2
   AND WHERE M IS  26.2757


QUADRATIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.


TO FIT 4 COEFFICIENTS.
----------------------
FORM IS - Y=A+B.(X-M)+C.(X-M)^2+D.(X-M)^3  WHERE
A =  18.476
B =  .792619
C = -.129671E-1
D = -.198025E-2
   AND WHERE M IS  26.2757


CUBIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.


   CONCLUSION.  BEST FIT IS LINEAR.
```

POOLED SAMPLES.

TO FIT 2 COEFFICIENTS.

FORM IS - Y=A+B.(X-M) WHERE
A = 20.8938
B = .731081
   AND WHERE M IS 29.6132

LINEAR FIT IS SATISFACTORY AT 1% LEVEL.
CORRELATION COEFFICIENT IS 0.99

TO FIT 3 COEFFICIENTS.

FORM IS - Y=A+B.(X-M)+C.(X-M)^2 WHERE
A = 20.8476
B = .731048
C = .156477E-2
   AND WHERE M IS 29.6132

QUADRATIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.

TO FIT 4 COEFFICIENTS.

FORM IS - Y=A+B.(X-M)+C.(X-M)^2+D.(X-M)^3 WHERE
A = 20.8372
B = .719442
C = .191365E-2
D = .118827E-3
   AND WHERE M IS 29.6132

CUBIC FIT IS SATISFACTORY AT 1% LEVEL.
NEW TERM IS NOT SIGNIFICANT AT 1% LEVEL.

   CONCLUSION. BEST FIT IS LINEAR.

SOURCE	SOS	DF	VAR	F
RES.1	6.00	28	0.21	
RES.2	6.30	28	0.23	
RES. POOLED	12.38	58	0.21	
SUM RES.1&2	12.30	56	0.22	0.97

END OF ANALYSIS.